American
GAS JOURNAL
Formerly American Gas Light Journal
EST. 1859

VOL. 117, NO. 12
WHOLE NO. 3367

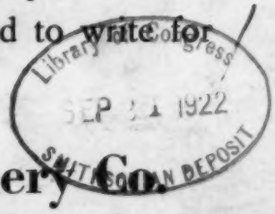
NEW YORK, SATURDAY, SEPTEMBER 16, 1922

Subscription $3 per year
$4 Canada $5 Foreign

Benzol Recovery at a Profit

The recovery of Benzol from Town and Coke Oven Gas has been attended by rapid development in the last few years. The demand and market for Benzol is assured for years to come as it is the starting point of various Synthetic Dyestuffs, Explosives, Drugs, etc. We have placed on the market a Recovery Plant which is automatic in its working, "fool-proof," highly efficient, and above all, economical in the use of steam and water, our efforts to utilize every available source of spent heat being attended with merited success.

In conjunction with our Centrifugal Scrubbers, we believe that this plant is unsurpassed for its high output and low working costs, and all interested are invited to write for further particulars and actual results.



The American Chemical Machinery Co.

Delaware Avenue and Reaney St. :: Chester, Pa.

Chemical Equipment for all purposes and any capacity

4428

INDEX TO CONTENTS, PAGE 4 ADVERTISERS' INDEX, PAGE 35

The Western Gas Construction Co.

NATION-WIDE SERVICE

First half of 1922, at work on these contracts

Holders
at
Bloomington, Ill.
Danville, Ill.
Lincoln, Neb.
Defiance, Ohio
New Albany, Ind.
Cadillac, Mich.
Belleville, Ill.
Bristol, R. I.
Buffalo, N. Y.
Oskaloosa, Iowa

Water Gas Sets
at
Griffin, Ga.
New Albany, Ind.
Carroll, Iowa
Quebec, Canada
Port Huron, Mich.
Newport, R. I.
Green Bay, Wis.
Appleton, Wis.
Sheboygan, Wis.
Havana, Cuba
Chillicothe, Mo.
DuQuoin, Ill. (2 sets)
Martinsville, Ind.
Shenandoah, Iowa
Gainesville, Fla.

Purifiers
at
Houston, Texas
New Albany, Ind.
Marshalltown, Iowa
Sheboygan, Wis.
Green Bay, Wis.
Cleveland, Ohio

Blower
at
Rocky Mount, N. C.

Exhauster
at
New Albany, Ind.

Tar Extractors
at
Albuquerque, New Mexico
Grand Junction, Col.

Ammonia Still
at
Lockport, N. Y.

Central Control Station and Hydraulic Lift
at
Newport, R. I.
Peoria, Ill.

Waste Heat Boilers
at
Chicago, Ill. (3)

Model H Reversing Valves
at
Port Huron, Mich.
Newport, R. I.
Peoria, Ill.

Valves and Piping
at
Bloomington, Ill.
Rio de Janeiro, Brazil

Bench Iron Work
at
Asheville, N. C.

Automatic Controls
at
Chicago, Ill. (6)

COMPLETE GAS PLANTS

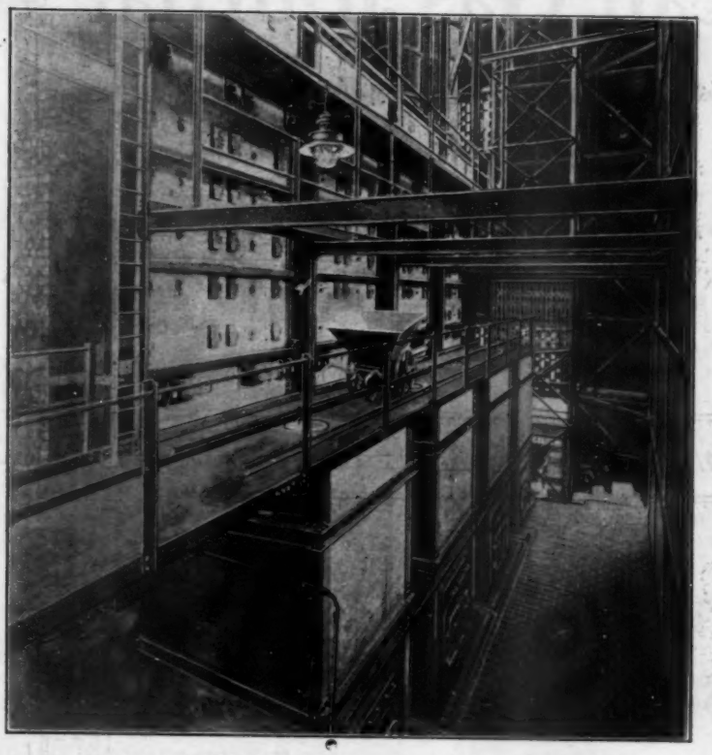
BUILT BY

The Western Gas Construction Co.

Fort Wayne, Indiana

Standard Water Gas Sets Purifiers Complete Gas Plants

GLOVER-WEST VERTICAL RETORTS



VIEW SHOWING PRODUCER SIDE OF RETORT BENCH

Illustration shows Horizontal Combustion Chamber Damper Boxes and Individual Bench Producers

The Glover-West system is noted for its ease of control by which high heats can be maintained over the length of the retort. Where high heats can be maintained without excessive local heating retort life is prolonged. Maintenance cost low, and output the best possible.

WEST GAS IMPROVEMENT CO.
of America, Inc.
150 Nassau St. New York

COMPANY MEMBER OF AMERICAN GAS ASSOCIATION

American Gas Journal

SIXTY-THIRD YEAR

Published Weekly by American Gas Light Journal, Inc., 53 Park Place, New York, N. Y.

ELBERT P. CALLENDER, Pres. S. G. KRAKE, Vice-Pres.-Treas. A. M. GLEASON, Sec'y

WALTER A. FAIRSERVIS, Editor

Ismar Ginsberg, Associate Editor

Contents of This Issue

The Intermittent Gas-Fired Enameling Furnace—By Frederic C. Mackey, Public Service Company of Northern Illinois..... 245

Combustion of Gaseous Fuels Judged from Gas Analyses — By A. G. Witting, Assistant Chief Engineer, Illinois Steel Company, Gary, Ind. 250

As the Journal Views It..... 255
Buildin Employee Good-will
The Chemical End of the Industry

Developments in Gas Technology — By Ismar Ginsberg, B.Sc., Chem. Engr., Associate Editor 261

Chemical Exposition Discusses Gas 263

Public Utilities Securities Market Report 265

News of the Gas Industry 266

Subscription $3.00 per year, including postage, in the United States, Mexico, Cuba, Porto Rico Hawaii or the Philippines; in Canada, $4.00; foreign, $5.00—Single Copies, 10 cents.

AMERICAN GAS JOURNAL. Sept. 16, 1922. Vol. 117, No. 12. Published weekly by American Gas Light Journal, Inc., New York, N. Y. Entered as second-class matter Jan 9, 1917, at the post-office at New York, N. Y., under the Act of March 3, 1879.

American Gas Journal
Formerly American Gas Light Journal

Vol. 117, No. 12 NEW YORK, SEPTEMBER 16, 1922 Whole No. 3367

The Intermittent Gas-Fired Enameling Furnace

The Necessity for Proper Equipment Is Paramount

By FREDERIC C. MACKEY, Public Service Company of Northern Illinois

As the American Gas Association slogan for this year is "More business—better business," it seems in order to take up the issue of "Better business." This may be construed in a number of ways. The gas people want more business and in order to get it must establish a greater feeling of confidence among their clientele.

What is more to the point than to try to bring the customer's attention to the necessity of installing proper equipment for industrial use? Too often in the past, in order to get industrial business, the gas engineer or industrial salesman has permitted the customer to dictate, "A couple of burners stuck in that old coal furnace will do," or "Well, we cannot afford to build a new furnace or oven right now." And what is the result? Many times the old furnaces leak like sieves and the grand finale is a customer "on again, off again." How many months will it be before that customer comes "on again"? And how much money will it take to get back the good-will of the lost customer?

This article is written with the idea of trying to make the reader see, whether he be gas utility man or manufacturer, how necessary it is to have proper equipment and to recover energy usually wasted. Only one phase of industrial art is considered and the writer hopes that similar methods may be applied to other lines of industry. If only some one reader can conceive a method of utilizing present wasted energy by referring to the following illustration, surely this article has served its purpose—"Better business—more business."

* * * * * *

During the last decade such astounding leaps have been made in the electrical apparatus field that many discoveries in heating units using fuels other than electricity have often been forced into the background. The authors of some articles which have appeared recently in technical publications have been so enthusiastic in their efforts to promote electrically operated equipment, that simplicity of control and cleanliness have been the paramount factors advanced. Too little has been said of fuel or power cost to the buyer and ultimate user of the equipment. It is not just to the prospective buyer to advance the idea that because an electric furnace may be controlled simply and with practically no dirt depositing on the work in process, that it is the most efficient proposition as an investment when used for certain types of work. Millions of dollars are tied up to-day in this country in equipment that is simply eating up profits and dividends because the operating costs were not considered at the time of purchase.

Coal has a place in industry where it stands supreme to-day, oil has a stamping ground that is impregnable, gas holds innumerable laurels and electricity holds out some inducements that are unapproachable.

It is a settled conclusion that the average equipment manufacturer or utility company is desirous of selling their customers something that will show results, not only from the viewpoint of efficient production operation, but also from the saving to the customer of needlessly expended money when the fuel cost is considered.

With many years in the electrical field and considerable gas experience, the writer of this article feels justified in giving an unbiased opinion when comparing electricity, gas, oil and coal in the vitreous enameling industries. Consultation with owners of plants, professional engineers and manufacturers of equipment, accurate cost charts based on equipment renewals and power or fuel expense, prove conclusively which installation is the most economical in the end. These factors and not purely selling points ought to be considered when any furnace equipment is purchased.

The gas figures shown in the following article were compiled from production results obtained by using the intermittent-type furnace. The furnaces from which these results were obtained are in daily use in the territory of the Public Service Company of Northern Illinois and operating under the jurisdiction of their industrial gas department.

Before the inception of these furnaces no such results were obtainable and it is safe to forecast that as soon as the enameling industry as a whole appreciates the speed and low operating cost of this type of installation, much new business will be obtained on industrial gas lines.

Coal

If coal is used as a fuel for vitreous enameling work, a muffle is necessary as the flue gases and particularly the sulphur fumes injure the article being baked. It not infrequently happens that small crevices open up in the muffle and entire batches of work are spoiled. The furnaces must be cooled for forty-eight hours and the break rejoined. Then the furnace must be brought up to heat again and another forty-eight hours is consumed. Then, too, the muffle must be torn out entirely every few months, the furnace overhauled and a new muffle installed.

Think of the time lost in any one year if a furnace must be cooled often for forty-eight hours in order

American Gas Journal

SIXTY-THIRD YEAR

Published Weekly by American Gas Light Journal, Inc., 53 Park Place, New York, N. Y.

ELBERT P. CALLENDER, Pres. S. G. KRAKE, Vice-Pres.-Treas. A. M. GLEASON, Sec'y

WALTER A. FAIRSERVIS, Editor

Ismar Ginsberg, Associate Editor

Contents of This Issue

The Intermittent Gas-Fired Enameling Furnace—By Frederic C. Mackey, Public Service Company of Northern Illinois..... 245

Combustion of Gaseous Fuels Judged from Gas Analyses — By A. G. Witting, Assistant Chief Engineer, Illinois Steel Company, Gary, Ind. 250

As the Journal Views It..... 255
Buildin Employee Good-will
The Chemical End of the Industry

Developments in Gas Technology — By Ismar Ginsberg, B.Sc., Chem. Engr., Associate Editor 261

Chemical Exposition Discusses Gas 263

Public Utilities Securities Market Report 265

News of the Gas Industry 266

Subscription $3.00 per year, including postage, in the United States, Mexico, Cuba, Porto Rico Hawaii or the Philippines; in Canada, $4.00; foreign, $5.00—Single Copies, 10 cents.

AMERICAN GAS JOURNAL. Sept. 16, 1922. Vol. 117, No. 12. Published weekly by American Gas Light Journal, Inc., New York, N. Y. Entered as second-class matter Jan. 9, 1917, at the post-office at New York, N. Y., under the Act of March 3, 1879.

American Gas Journal
Formerly American Gas Light Journal

Vol. 117, No. 12 NEW YORK, SEPTEMBER 16, 1922 Whole No. 3367

The Intermittent Gas-Fired Enameling Furnace

The Necessity for Proper Equipment Is Paramount

By FREDERIC C. MACKEY, Public Service Company of Northern Illinois

As the American Gas Association slogan for this year is "More business—better business," it seems in order to take up the issue of "Better business." This may be construed in a number of ways. The gas people want more business and in order to get it must establish a greater feeling of confidence among their clientele.

What is more to the point than to try to bring the customer's attention to the necessity of installing proper equipment for industrial use? Too often in the past, in order to get industrial business, the gas engineer or industrial salesman has permitted the customer to dictate, "A couple of burners stuck in that old coal furnace will do," or "Well, we cannot afford to build a new furnace or oven right now." And what is the result? Many times the old furnaces leak like sieves and the grand finale is a customer "on again, off again." How many months will it be before that customer comes "on again"? And how much money will it take to get back the good-will of the lost customer?

This article is written with the idea of trying to make the reader see, whether he be gas utility man or manufacturer, how necessary it is to have proper equipment and to recover energy usually wasted. Only one phase of industrial art is considered and the writer hopes that similar methods may be applied to other lines of industry. If only some one reader can conceive a method of utilizing present wasted energy by referring to the following illustration, surely this article has served its purpose—"Better business—more business."

* * * * * *

During the last decade such astounding leaps have been made in the electrical apparatus field that many discoveries in heating units using fuels other than electricity have often been forced into the background. The authors of some articles which have appeared recently in technical publications have been so enthusiastic in their efforts to promote electrically operated equipment, that simplicity of control and cleanliness have been the paramount factors advanced. Too little has been said of fuel or power cost to the buyer and ultimate user of the equipment. It is not just to the prospective buyer to advance the idea that because an electric furnace may be controlled simply and with practically no dirt depositing on the work in process, that it is the most efficient proposition as an investment when used for certain types of work. Millions of dollars are tied up to-day in this country in equipment that is simply eating up profits and dividends because the operating costs were not considered at the time of purchase.

Coal has a place in industry where it stands supreme to-day, oil has a stamping ground that is impregnable, gas holds innumerable laurels and electricity holds out some inducements that are unapproachable.

It is a settled conclusion that the average equipment manufacturer or utility company is desirous of selling their customers something that will show results, not only from the viewpoint of efficient production operation, but also from the saving to the customer of needlessly expended money when the fuel cost is considered.

With many years in the electrical field and considerable gas experience, the writer of this article feels justified in giving an unbiased opinion when comparing electricity, gas, oil and coal in the vitreous enameling industries. Consultation with owners of plants, professional engineers and manufacturers of equipment, accurate cost charts based on equipment renewals and power or fuel expense, prove conclusively which installation is the most economical in the end. These factors and not purely selling points ought to be considered when any furnace equipment is purchased.

The gas figures shown in the following article were compiled from production results obtained by using the intermittent-type furnace. The furnaces from which these results were obtained are in daily use in the territory of the Public Service Company of Northern Illinois and operating under the jurisdiction of their industrial gas department.

Before the inception of these furnaces no such results were obtainable and it is safe to forecast that as soon as the enameling industry as a whole appreciates the speed and low operating cost of this type of installation, much new business will be obtained on industrial gas lines.

Coal

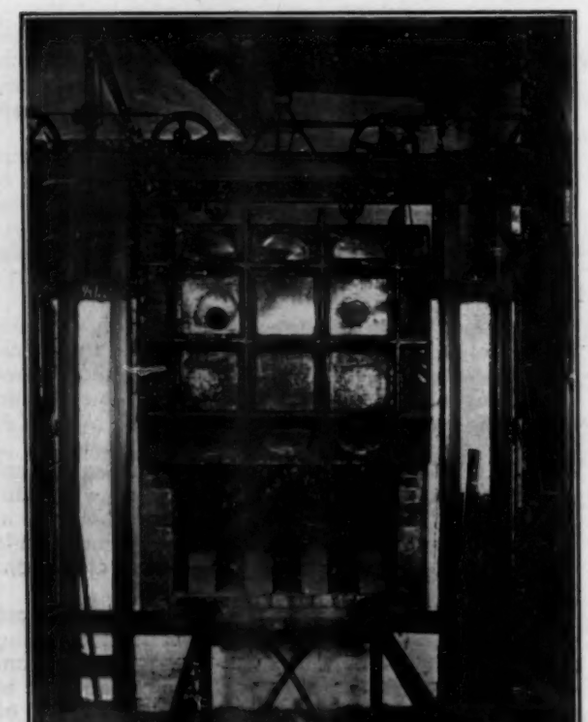
If coal is used as a fuel for vitreous enameling work, a muffle is necessary as the flue gases and particularly the sulphur fumes injure the article being baked. It not infrequently happens that small crevices open up in the muffle and entire batches of work are spoiled. The furnaces must be cooled for forty-eight hours and the break rejoined. Then the furnace must be brought up to heat again and another forty-eight hours is consumed. Then, too, the muffle must be torn out entirely every few months, the furnace overhauled and a new muffle installed.

Think of the time lost in any one year if a furnace must be cooled often for forty-eight hours in order

to repair breaks or reconstruct the muffle or flues, which will take from four to ten days additional. Think of the quantity of coal burned for forty-eight hours each time in order to bring the furnace back to burning temperature. Cost figures from various plants show that the average "muffle expense" for an oven with 3x4x12 ft. enameling space is approximately $100 per month.

Work Not Always High Grade

The work turned out is not always of the highest grade and much of it must go as seconds or be



Interior View of Intermittent Gas-Fired Enameling Furnace Showing Solid Bottom and Compact Construction

thrown in the scrap heap. This is more evident the longer the furnace is in use because the hearth sags making it impossible to get even or flat work. Finally the collapse of the muffle means rebuilding. Another reason for poor work is that dust from the coal and ashes is constantly in the air of the workroom, causing rough surfaces and spots on the article in process.

Firemen must be at work twenty-four hours a day coaling the furnace and regulating the heat. It is well to realize, too, that an even temperature is impossible with even the best constructed coal furnace in use to-day. Here we have uneven or spot heat to contend with, which means spoiled work and furnace deterioration. A good grade of coal must be used and, as some saving must be made, the coal is bought in large quantities. But interest on the storage space and on the investment in the coal itself is no small item as coal must be bought in advance and paid for. Add to this deterioration of the coal, unloading charges and freight and a pretty expensive article is the sum total. Gas is used and the customer pays for it a month to six weeks after using.

Oil

Now consider oil.

If a muffle is used to prevent the products of combustion from coming into contact with the work in process, the heat from oil flames is so terrific that renewals of brickwork and muffle are much more frequent than with coal.

Some plants have found it necessary to repair or rebuild their muffles as often as every six weeks. Here is involved material and maintenance expense as well as loss of production. As a general rule, it has been found necessary to have a spare furnace ready to operate for every three in operation because of this muffle breakage. This "frozen" capital investment and idle floor space item should most certainly be considered and charged to operating costs. If the floor space of a plant is limited, it is apparent that the type of furnace operating with but few shutdown periods is very desirable.

If the intermittent type of heating is used the interior of the furnace must be much larger than with gas, because oil is slower in burning and consequently requires much more space to develop the same amount of heat. This larger space results in a necessarily higher B.t.u. consumption, due to higher radiation losses and the greater mass of the furnace being heated.

Some of the Costs Involved

Figure freight, switching, heating and unloading charges on tank cars, pumping from cars to storage tanks, pumping from tanks to burners; add to this leakage, burner repairs, cost of compressed air or steam for atomizing and interest on storage-tank space, maintenance on oil systems, also heating of oil tanks in cold weather, and a pretty healthy bill is the result.

Another item upon which it is hard to put a dollars and cents figure is the loss of production due to non-delivery of oil when there is a market demand for it. Large users of oil usually contract for it and most of them know from experience that when there is a demand for oil at a higher figure than their contract calls for, the oil companies are very prone to sell on the market and let them wait. This makes it necessary for the user either to go out on the open market or else install storage capacity to take care of from four to six weeks' supply. Many plants cannot afford this extra expense and even though they can it is not a positive insurance against shortage. The writer knows from his own experience what it means to have a stock of 80,000 gal. of oil to start with and a consumption of 3,000 gal. per day and yet be compelled to shut down due to non-delivery.

Electricity

When electricity is used the muffle is eliminated entirely. Heating elements of nichrome strips wound on racks are mounted directly in the enameling space of the furnace. Here we have an ideal combination,

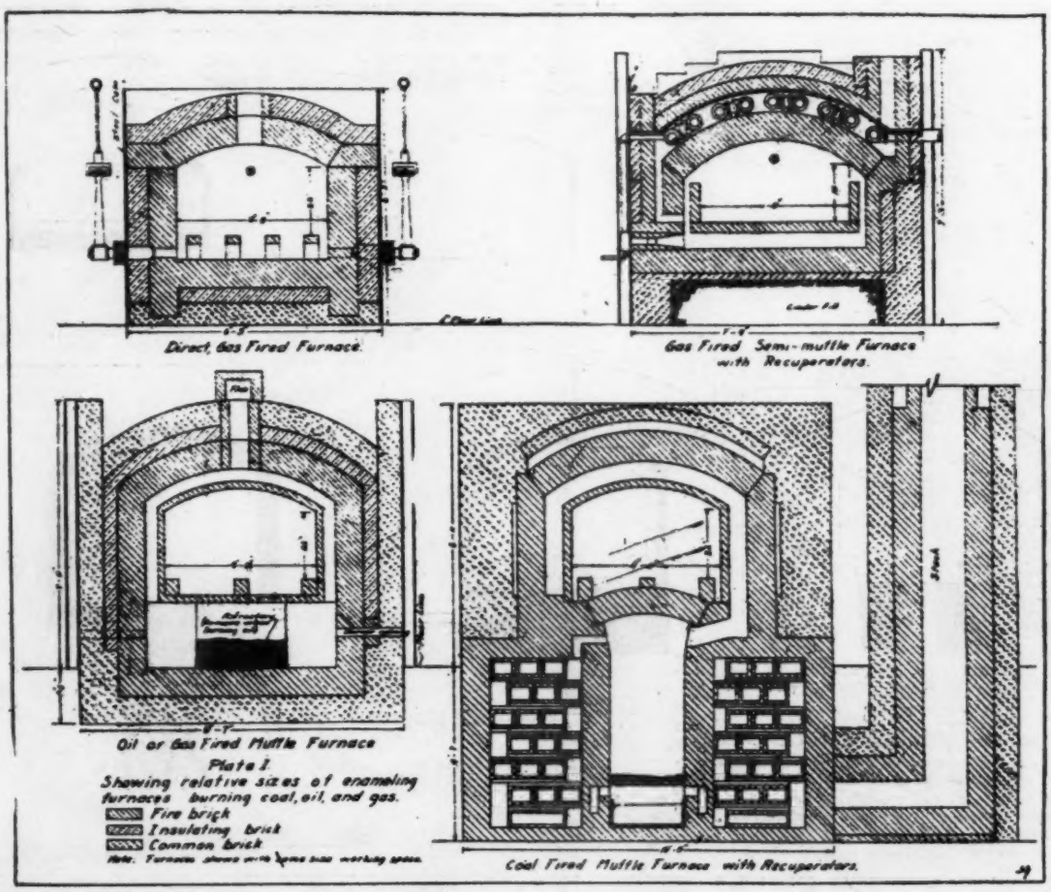

Direct Gas Fired Furnace.
Gas Fired Semi-muffle Furnace with Recuperators.
Oil or Gas Fired Muffle Furnace
Plate I.
Showing relative sizes of enameling furnaces burning coal, oil, and gas.
Fire brick
Insulating brick
Common brick
Coal Fired Muffle Furnace with Recuperators.

Plate I

i. e., direct heat and no products of combustion to spoil the work in progress. Again, the furnace may be heated from cold to 1,700 deg. Fahr. in twelve hours. Insulating material properly applied provides that the furnace may be shut off for twelve hours and be up to working temperature in about one hour when cut in again.

There is also no muffle expense, minimum spoilage and even, automatic temperature control. Add to this saving of firemen's pay, coal storage space or oil tank space and the outfit is ideal providing the power expense is not to be considered.

Gas

How about gas?

It is commonly assumed that with gas a muffle is required and here is where the mistake is made. No muffle is required with a gas installation. Neither is a sheet iron covered furnace necessary for perfect work. Before proceeding further the reader is asked to examine closely Plate No. 2 which will bring to mind immediately the value of firing directly in the working chamber of the furnace. Hardly more than a glance will show how valuable a saving can be made by not heating up a lot of muffle, waste brick, etc.

The art of enameling is a very old one, but in spite of that fact there is very little general knowledge on the subject. Each manufacturer seems to have a different formula for his particular type of work. There are various established formulas compounded of known quantities of basic raw materials, but the flux required to produce the desired results varies considerably. Almost every manufacturer's work requires a different proportion, according to the gauge, weight and hardness of metal burned. Some work requires a furnace temperature of 1,200 deg. Fahr. Various other requirements range as high as 2,000 deg. Fahr.

Assuming that any one manufacturer may require four to five varying temperatures differing as much as 500 to 600 deg. and would want to use the same furnace in the same working day, it is very necessary to have equipment so flexible that the heat may be stepped up in the shortest possible time. To make these quick changes with a coal furnace is impossible. To make them with an electric furnace is possible but costly and takes about five times as long as with a gas furnace. For example, an electric furnace will step from 1,200 to 1,800 deg. in one hour. A gas furnace will accomplish the same feat in ten to twelve minutes. The furnace best suited for these quick changes is the intermittent gas-fired type.

This furnace is operated in a somewhat different manner than any other gas-fired furnace in use at the present time. Before the discovery of this method, gas could not be burned in the firing chamber of the

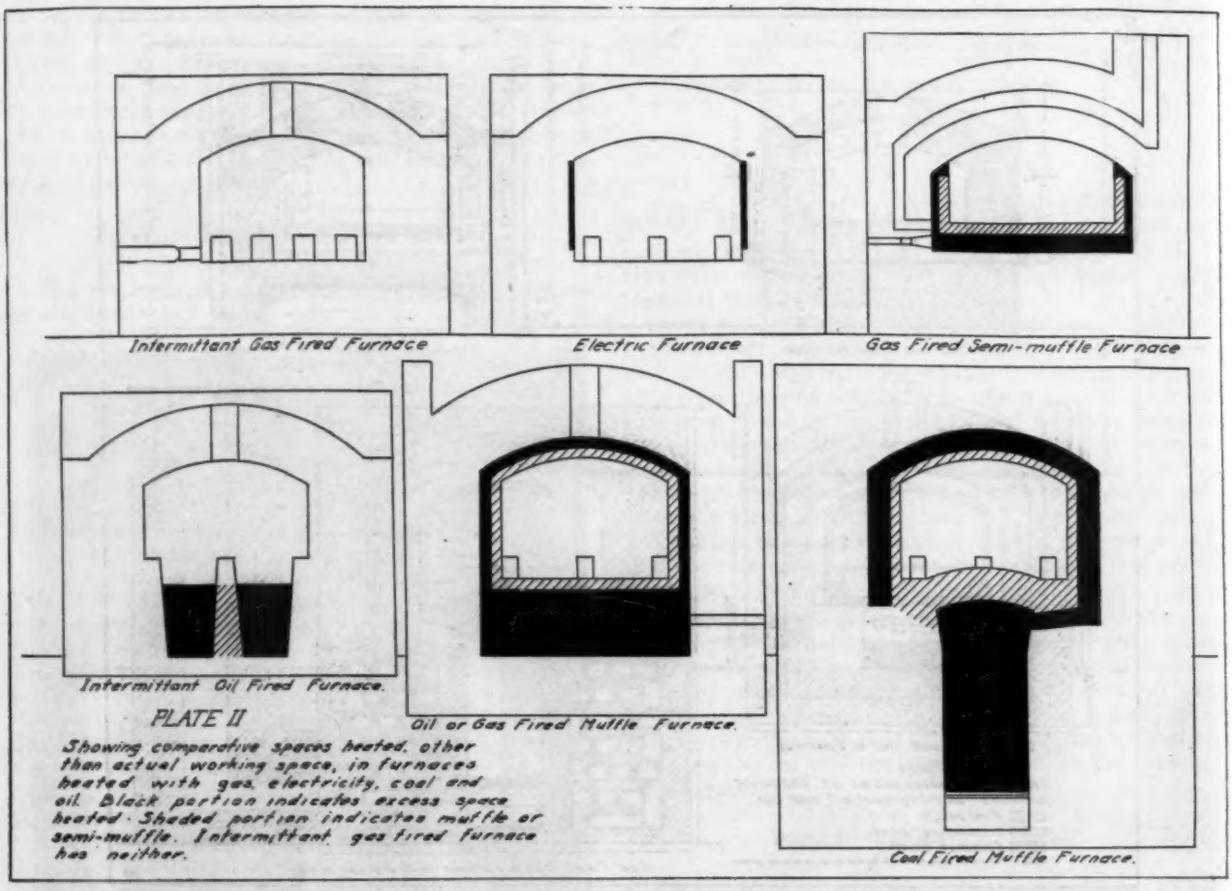

Intermittant Gas Fired Furnace
Electric Furnace
Gas Fired Semi-muffle Furnace
Intermittant Oil Fired Furnace.
Oil or Gas Fired Muffle Furnace.
Coal Fired Muffle Furnace.

PLATE II

Showing comparative spaces heated, other than actual working space, in furnaces heated with gas, electricity, coal and oil. Black portion indicates excess space heated. Shaded portion indicates muffle or semi-muffle. Intermittant gas fired furnace has neither.

furnace without the products of combustion coming into contact with the work in process. For this reason a muffle or a semi-muffle was used when gas was burned continuously. It can be readily understood that when a muffle is used a terrific heat must be maintained on the outside in order to get the required heat in the baking chamber. This means high fuel cost. If the semi-muffle is used the cost is somewhat modified but the problem of not getting the full value of the heat on the work direct still exists. The intermittent type therefore should receive great consideration when it is understood that practically all the heat units may be conserved.

High Pressure Used

The gas for this furnace is supplied from the mains or booster at high pressure of from five to ten pounds. The gas flows through high-pressure inspirators (mixers) which, when once set, require no changes in adjustment. This correct mixture of gas and air now enters the burner and hence to burner tunnel. Practically all combustion takes place in this burner tunnel so that the burning chamber of the furnace receives simply hot gases. The walls immediately become intensely hot. The color of the interior of this furnace is beautifully even from front to rear wall and the existence of spot heat is unknown.

As soon as the pyrometer registers the required temperature, the gas is snapped off, the furnace door is opened, work placed in the burning chamber and burned by the reflected heat from the walls and floor. It can be readily seen that with the gas turned off the products of combustion never come into contact with the work in process. The furnace working space is ten feet long, four feet wide and thirty-six inches high. This space is equivalent to a twelve-foot muffle furnace, because the supporting pins may be loaded with material within six inches of the door. Compare this with the coal furnace, where work to be burned must be left two feet or more away from the door and rear wall.

Radiation losses are reduced to a minimum, for back of the fire-brick interior are three layers of Sil-O-Cel brick and finally a layer of common brick to complete the exterior. With a properly constructed furnace very wonderful results may be obtained. Care must be taken that proper insulation is furnished. Too little attention to this factor will most certainly discount maximum results in any furnace, no matter what fuel is used. The door must be built to hold back the heat; simply mounting a slab of tile in an iron band does not constitute a good job. The cast-iron door which holds three to four inches of insullation and a layer of fire-brick next to the furnace opening is probably the ideal unit to consider.

The four supporting piers in the interior of the furnace are of six-inch tile, which adds considerable bearing surface to hold racks and ware, preventing

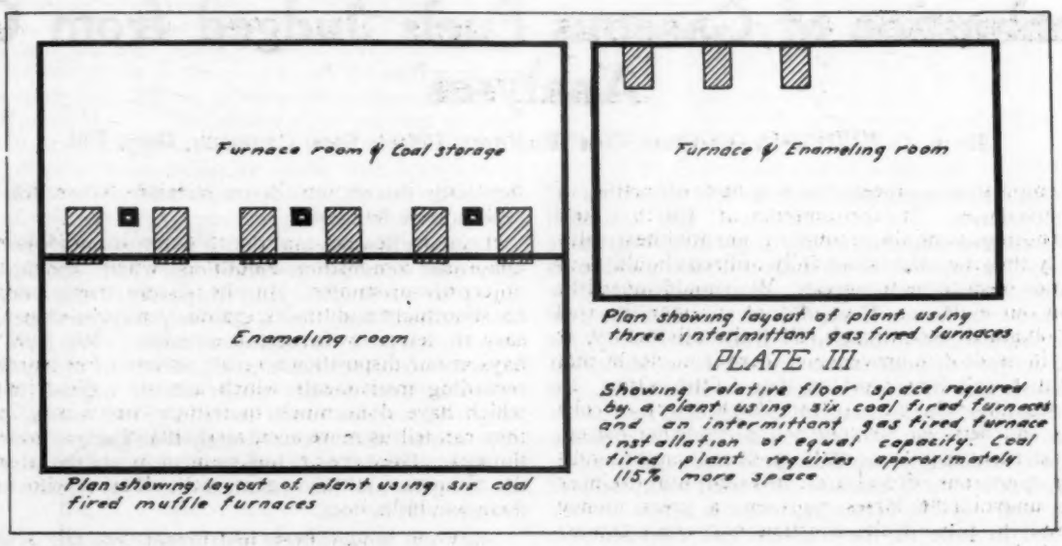

Furnace room & Coal storage
Enameling room
Plan showing layout of plant using six coal fired muffle furnaces
Furnace & Enameling room
Plan showing layout of plant using three intermittant gas fired furnaces

PLATE III

Showing relative floor space required by a plant using six coal fired furnaces and an intermittant gas fired furnace installation of equal capacity. Coal fired plant requires approximately 115% more space

bending of work when being burned. The foregoing description of this intermittent furnace will no doubt give the reader an idea of the construction in general.

A close scrutiny of plate No. 1 will show the relative size of coal, oil and gas furnaces. It is very apparent the amount of floor space that may be saved by installing the direct-fired intermittent furnace, to say nothing of the economy in brick. Add to the additional furnace space a coal-storage room and fireman's room for the coal furnace or oil-storage tanks and pump room for the oil-fired furnace and the gas outfit looks admirable from this point of view alone. Now see plate No. 3 and a comparison of the floor space of a coal and gas enamel plant may be gained.

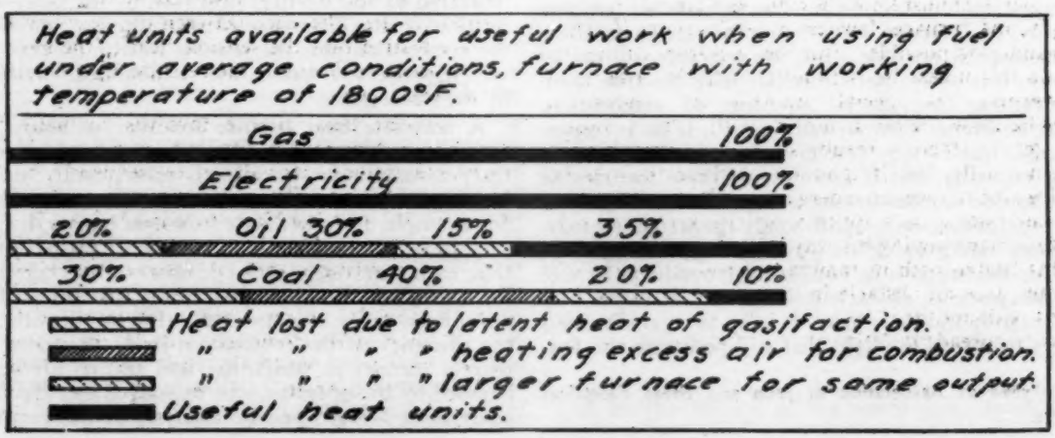
Using the Flue Gases

Another important item which is not a small one should be carefully considered when planning for an installation of this order. The flue gases, leaving the furnace, are of considerable intensity. These gases may be converted for various uses. By mounting a waste-heat steam boiler or a waste-heat hot-air box on the furnace flue it is possible to make a big saving, for the power generated in the boiler or box should be credited to the fuel cost. If a waste-heat steam boiler is used, the flue gases contain enough heat to generate five horse-power per hour. Gases leaving the steam boiler will still show a temperature of 300 to 400 deg. This heat may be utilized for heating air to be used in the dry room or in the workroom itself. These are merely suggestions and it may readily be seen that there are many other uses to which this waste heat may be applied, dependent entirely upon the individual plant requirements.

Carefully compiled records of quantities of production and cost during more than a year's work with intermittent gas-fired furnaces, after the experimental stage had been passed, have proved conclusively that, with gas at 90 cents per thousand cubic feet and 550 B.t.u. content, this method of vitreous enameling is by far the most efficiently economical fuel of all.

The following table shows the comparative number of square feet of material baked per hour, cost per hour and cost per hundred square feet of ware baked in various types of furnaces of approximately

(*Continued on page* 256.)


Heat units available for useful work when using fuel under average conditions, furnace with working temperature of 1800°F.
Gas 100%
Electricity 100%
20% Oil 30% 15% 35%
30% Coal 40% 20% 10%
Heat lost due to latent heat of gasifaction.
" " " " heating excess air for combustion.
" " " "larger furnace for same output.
Useful heat units.

Combustion of Gaseous Fuels Judged from Gas Analyses*

By A. G. WITTING, Assistant Chief Engineer, Illinois Steel Company, Gary, Ind.

We combustion engineers have a field of action of great importance. The consumption of fuel in a steel plant is enormous and the amount of potential heat value carried by this fuel that is not fully utilized should to us at all times seem to be too great. We should indeed be remiss in our endeavor if we did not consider the fuel practice obtained, even though relatively satisfactory, as standing in need of improvement; there is no doubt that even what is well done could be done a little better. In a plant like ours, where up to 150,000,000 cu. ft. of coke oven gas and between 800,000,000 and 900,000,000 cu. ft. of blast furnace gas are daily produced, and in addition over 2,000 tons of coal are converted into producer gas, the unavoidable losses represent a great money value; and in spite of the constant and conscientious efforts of the management to minimize it, the waste amounts high when translated into pounds of coal equivalents. We are, all of us, trying our hardest to combat this condition, even if our efforts often show very discouraging results. But while it is only the practical results that count and theorizing often leads us to try to find excuses instead of remedies, nevertheless it is only through the correct application of theories (which themselves should be based entirely on practical results) that practical results are obtained. They are evolved from experience, but so many factors play in that the deductions drawn from this experience sometimes may stand in need of correction. It is, as I understand it, one of the objects of the Combustion Section of the Association of Iron and Steel Electrical Engineers to have its members bring such questions under discussion for the purpose of getting a better understanding of some of the phenomena that rule combustion.

The prime object of our work is to cut down fuel consumption, to obtain perfect combustion with a minimum surplus of air. In our pursuit of this goal we should, of course, direct our efforts to find improved methods and means for producing such a combustion, and there is a large room for improvement in the design of burners, furnaces, etc. But we should never lose sight of the fact that these are only tools and that the handling of the same in the most efficient way is of greater importance, that the operator must know how to regulate his fuel and air supply, his furnace, burner or producer in as effective a manner as possible. But the operator will not be able to do this unless he is familiar with the true theories governing his special problem of combustion. Whether he knows them or not, he will, if he is conscientious, get satisfactory results so long as everything is running normally, but if ignorant of these theories he will not be able to meet an emergency. Proceeding from wrong conclusions, he is apt to apply the wrong remedy. He is like a man groping his way in a fog; as long as he travels his beaten path in familiar surroundings he will get on, but place an obstacle in his way that forces him out of his path and he is lost. It is up to us combustion engineers to spread the light that will penetrate the fog, but to do this we must know ourselves where the light is and how to handle it.

It might then be said that it is not so much normal as abnormal combustion conditions which should be the object of our studies. But the passage from a normal to an abnormal condition is gradual, and consequently not easy to detect by casual observation. We have nowadays at our disposition a great variety of measuring and recording instruments which are of a great help and which have done much to reduce fuel waste, because they can tell us more accurately than the eye how everything is. They are as important to us as the barometer, the compass and the sextant to the skipper, who without them would be lost.

But even though these instruments can tell us and the operator when a condition becomes abnormal, there are instances when we cannot directly from them detect what caused this condition, which is the only thing that really counts. It becomes necessary for us to examine closer into the process of combustion, and the means at our disposition for such an examination is the old standby, the gas analysis.

It is my intention with this paper to discuss the significance of gas analyses or, more exactly, to advocate the better utilization of one kind of gas analysis, the waste gas analysis, and warn against the indisicriminate use of another kind, the producer gas analysis. In connection with this latter question I will also present some viewpoints on the important but often sidetracked function held by those constituents of the producer gas which, being condensable, escape our analyses, and lay before you the result of some investigations into the nature of these tarry vapors.

A. Waste Gas Analysis

For metallurgical purposes three gaseous fuels are used: blast furnace gas, coke oven gas, and producer gas. Their heat value and the efficiency of their combustion is judged from analyses and from the heat balance indicated by them; heat balance meaning the heat delivered to and usefully absorbed by the place of combustion, or the difference between the heat developed in the combustion plus the sensible heat in the gas and the air (if preheated) minus the sensible heat carried away by the waste gases.

A complete heat balance involves so many factors that it, to a large extent, depends on guesswork or arbitrary assumptions—its value is consequently, to say the least, questionable. To make up such a heat balance, for example, for a hot blast stove gas burner, it is necessary to obtain not less than nineteen items of information, each requiring a series of observations taken during the same time. I am tempted to say that such a feat has never been really accomplished. But, on the other hand, the efficiency of the combustion itself, the more or less correct manner in which the fuel and its air supply is handled by the operator, can be judged exactly from an analysis of the gas and an analysis of the products of

*Paper read at Association of Iron and Steel Electrical Engineers.

combustion, provided that both samples are taken simultaneously, not the one immediately after the other.

It is clear that the highest efficiency is developed when all the combustibles in the gas and all the oxygen in the air are consumed, leaving in the waste gases nothing but CO_2, N_2 and H_2O. This means a 100 per cent reaction and is in practical operation not attainable. The fuel is burnt either with an oxidizing flame, with a surplus of air, indicated by the presence of oxygen in the waste gas analysis, or with a reducing flame, the air supply being below requirements so that combustibles are carried away with the waste gases and appear in their analysis. It also happens that both oxygen and combustible gases at the same time occur in the waste gases. In the latter two cases a direct comparison between the two analyses is not possible; the composition of the waste gases cannot be calculated directly from the gas analysis. Under these conditions it has been customary to figure the waste gases produced on the assumption that all the carbon in the original gas is found in the waste gas, the volume of the latter comparing with the volume of the former as the CO_2 that would have been produced by complete combustion compares to the CO_2 in the waste gas analysis plus the CO_2 that would have been produced by the unburnt combustibles.

Now, very often in metallurgical operation the waste gases contain CO_2 which is not derived from the fuel. When this occurs there exists, at least to the writer's knowledge, no published method by which the combustion process can be calculated. It is the purpose of this paper to set forth a series of simple formulas which will assist in solving such problems.

1. Complete Combustion

For the numerical examples introduced in the paper or in the appendices attached to it I have been using the standard values for chemical reactions. As a help to anybody who may want to check my calculations I have collected these values in a table which appears in Appendix No. 1.

I have assumed that the air by volume contains 21 per cent oxygen and 79 per cent nitrogen, and that accordingly 1 cu. ft. of oxygen in the air is associated with 3.762 cu. ft. of nitrogen, making 4.762 cu. ft. of air. The high or gross heat values are used for blast furnace gas and coke oven gas, because corroborative calorimetrical tests are generally made with these gases. For producer gas the lower or net values are mostly used, as this gas is not tested by calorimeter. This is, of course, not a rule laid down, only an explanation of my method of calculation.

To determine the efficiency of a burner or a furnace operation we have obtained our two gas samples, the waste gas sample being collected at a point where any danger from outside influence—air leakage, for example—is as far as possible eliminated. If the analysis of the waste gas does not show any combustibles present, the chances are that oxygen is found. The question then naturally is: How much surplus air has been admitted? It will be necessary first to calculate the requirements and results of a theoretically perfect combustion. Having thus obtained the volume of the products of combustion, neglecting the condensible moisture, the amount of air present in the waste gases, as indicated by a certain percentage of oxygen and the total volume of waste gases, is obtained by means of the following formulas:

$$(1)\quad A = \frac{Pa}{21\text{-}a} : W = \frac{21P}{21\text{-}a}$$

When A = amount of surplus air.
P = products of complete combustion (minus moisture).
W = total amount of waste gas = A + P.
a = percentage of oxygen in waste gas.

Appendix No. 2 gives an example of such a calculation when the fuel was blast furnace gas. One hundred cubic feet of this gas required 71.43 cu. ft. of air and gave 153.43 cu. ft. of waste gases (not counting the H_2O). The waste gas analysis showed 1.8 per cent oxygen, which meant that the waste gases contained 14.38 cu. ft. surplus air, corresponding to a surplus of 20 per cent, and that the total amount of waste gases produced from 100 cu. ft. of gas was 167.81 cu. ft., to which, of course, has to be added the amount of water vapor calculated from the gas analysis plus the moisture contained in 100 cu. ft. of gas and 85.81 cu. ft. of air.

2. Incomplete Combustion

The usual method of figuring the volume of the waste gases, when the combustion has been incomplete, from the carbon contents does not need any demonstration here, because this method, as stated in the introduction, cannot be employed if any carbon dioxide has been added to the waste gases from any other source than the fuel gas itself, as usually is the case in an open-hearth furnace. Besides, it offers no advantage over the one I am going to submit, and which is based on the air present, whether used for combustion or left as a surplus in the waste gases. The formula may appear unwieldly and downright formidable. But in the by far greater majority of cases most of the factors in the formula will be eliminated as not appearing in the analysis.

Composition of Fuel Gas		Composition of Waste Gas		
	Analysis		Analysis	Volume
CO_2	a%	CO_2	h%	hw
C_2H_4	b%	C_2H_4	j%	jw
CO	c%	CO	k%	kw
H_2	d%	H_2	l%	lw
CH_4	e%	CH_4	m%	mw
C_6H_6	f%	C_6H_6	n%	nw
N_2	g%	N_2	p%	pw
O_2	o%	O_2	q%	qw
H_2S	s%			
	100%		100%	100w

$$(2)\quad w = \frac{y + v - o}{x + z - q} \text{ if } x = \frac{21}{79}p;\ v = \frac{21}{79}g$$

$$y = 3b + \frac{c}{2} + \frac{d}{2} + 2e + 7\tfrac{1}{2}f + 1\tfrac{1}{2}s$$

$$z = 3j + \frac{k}{2} + \frac{l}{2} + 2m + 7\tfrac{1}{2}n$$

After the volume of the waste gases in this manner

has been established, other information wanted is obtained by the following equations:

$$(3)\ \text{Air present: } Ap = \frac{100\,(pw - g)}{79}$$

$$(4)\ \text{Surplus air: } As = \frac{100\,qw}{21}$$

(5) Air needed for complete combustion—

$$Ac = \frac{100\,(y - o)}{21}$$

$$(6)\ \text{Useful air: } Au = Ap - As = \frac{100\,(y - zw - o)}{21}$$

$$(7)\ Co_2 \text{ addition} = w\,(h + 2j + k + m + 6n) - (a + 2b + c + e + 6f)$$

In Appendix No. 3 the derivation of the formulas is explained and the application of the same is illustrated by a couple of examples with check-ups which prove the correctness of the formulas.

As it is not necessary, when using this method for calculating the waste gases, to figure the results of a theoretical combustion, but it always is required to know the amount of water vapor produced, the same will be obtained by means of the following formula:

$$(8)\ H_2O = (2b + d + 2e + 3f + 2s) - w\,(2j + 1 + 2m + 3n)$$

With the assistance of these formulas any waste gas analysis, no matter what it contains or in what manner the CO_2 has been produced, can be translated into cubic feet, providing an analysis of the fuel gas has been taken simultaneously with the waste gas analysis. It is, consequently, no longer necessary to arrive at your deductions by guessing. You will know positively how great a percentage of the combustibles in the gas has passed unconsumed through the furnace or how great the surplus of air has been or what percentage of the CO_2 has been added to the gases from the material in the furnace. In this way it will also serve as a check on the analysis itself.

B. Producer Gas Analysis

As just stated, it is at all times necessary to give proper attention to the amount of condensable matter in the gases which the analyses unfortunately neglect. This necessity becomes still more important when the question is of producer gas, which always carries in addition to water vapor a certain amount of so-called tarry vapors, products of the distillation of the volatile matter of the coal, which cannot be analytically determined. Writers on the subject generally satisfy themselves with calling attention to their existence, and then forget them, continuing the discussion as if producer gas was non-condensable like blast furnace gas or coke oven gas.

It is the object of the following part of the paper to make clear how erroneous the conclusions might be which are drawn under the assumption that the ordinary producer gas analysis shows up a hundred per cent of the gas generated from the coal in the producers.

The writer has given this phase of the fuel problem considerable study and succeeded to construct from analyses the probable composition of the volatile matter in Indiana coal from the Clinton district. It would require too much space, and be partly outside the subject, to repeat in detail the methods employed; and I will, therefore, content myself with saying that a double cross-checking of the result obtained verified the same remarkably well.

The laboratory analysis of the coal in question gives the following composition:

Volatile matter	35.51%	Ultimate Analysis	
Fixed carbon	48.28%	Total carbon	67.91%
Ash	9.41%	Hydrogen	4.57%
Moisture	6.80%		
	100.00%		

The constituents of the volatile matter determined by a series of analyses and with the assistance of analogies from analyses of similar coals made by the Bureau of Mines were as follows:

Condensable hydrocarbons	10.052%
Permanent gases	18.262%
Neutral condensates, H_2O and H_3N	7.196%
	35.510%

Our method of taking producer gas samples is to collect them unknown to the gas makers regardless of the conditions of the producers, so as to get as true an average as possible and not—as too often is the case—a series of analyses that look very attractive on paper but mean nothing to the one that supervises the operation of the producers.

Selecting, for the purpose of proving my suspicions, with regard to the true value of an analysis, the latest fifty analyses taken as a daily routine work at our open-hearth furnaces, I obtained an average composition of the gas produced from this coal of:

CO_2	8.0%
C_2H_4	0.4%
CO	20.3%
H_2	8.1%
CH_4	2.6%

The average *low* heat value was 118 B.t.u.

Appendix No. 4 gives more in detail the composition of the coal and the composition of the gas.

The gas is, as everybody knows, produced from the coal partly through direct gasification of the fixed carbon by the blast (a mixture of air and steam) and partly through distillation of the volatile matter. In addition, secondary reactions of varying nature have taken place stabilizing the hydrocarbons in the volatile matter into gases that are permanent in heat. These processes may be considered either as a series of pyrogenetic reactions, whereby the hydrocarbons, at the high temperature prevailing, are condensed into higher compounds and free carbon, or cracked up into more simple non-condensable compounds and free hydrogen, or else as direct reactions between the hydrocarbons and the distillation products (particularly CO_2 and H_2O and, of course, oxygen if due to a thin fuel bed or channels in the same, the oxygen has not all been absorbed in the gasification zone), form-

ing CO and H_2. A true understanding of these reactions is of highest importance in the correct operation of a producer, and they offer a wide field of study which, however, is outside the scope of this paper. I will therefore content myself to call the attention to them.

In considering the influence of these secondary reactions on the composition of the gas we might assume three possibilities:

1. That only the first kind of reactions takes place, viz.: that all the tarry vapors enter the gas as stable hydrocarbons.

2. That only the second kind of reactions takes place, viz.: that all the tarry vapors are broken up and converted into permanent non-condensable gases, so that the gas analysis represents 100 per cent of the gas produced.

3. That both kinds of reactions occur simultaneously, the preponderance of the one or the other depending on operating conditions, but with the result that the gas always contains some condensable hydrocarbons and the gas analysis consequently does not represent all the gas.

It being generally conceded that the gas receives its luminosity from the hydrocarbons, and that this luminosity is of highest importance, at least in open-hearth practice, it follows that the quality of the gas is improved to the degree in which the first kind of reactions dominate.

Now, there may exist a difference of opinion on this question; in a paper recently read before the American Society of Mechanical Engineers not only the need of luminosity in gas used at open hearths was questioned, but the author tried to prove that the tarry vapors in the gas had nothing with the luminosity to do. But I take the stand that luminosiy is a necessity and that while luminosity might be obtained in other ways, it is imparted to *producer gas* practically altogether from the hydrocarbons in the gas, which dissociate in the flame, precipitating solid carbon, which not only when brought to a white glow gives off a dazzling light but, being equal to the so-called "perfect black body," possesses greater radiating power than any other solid. The author referred to presents some figures to prove "that the illuminants in the gas are non-essential." Now, against this statement I want to call your attention to the fact that, as everyone unfortunately is fully aware, the waste gases from a fire where coal or a gas produced from coal is the fuel, might issue from the stack as a dense black smoke. This color of the smoke is due to soot or carbon particles dissociated from hydrocarbons in the flame, but for one reason or other cooled below their ignition point. No matter how bad the combustion, it must be assumed that never 100 per cent of the carbon in the gases leaves the combustion chamber unconsumed; that, in other words, this soot in the waste gases represents only *a fraction*, even if it is a large one, of the carbon present in the flame, and there heated to the temperature of the flame. It is claimed that the actual carbon in dense black smoke amounts to 1 per cent of the carbon in the coal, and that this carbon under the microscope appears as clusters of small particles about 0.000002 in diam-

I think everybody will agree that these clusters, or visible smoke particles, will pass through a hundred-mesh sieve, if they are not smaller. It is easy to calculate that under this assumption (= 300 deg. Fahr.) would contain about 5,400 such particles, evenly distributed in the gas. Assuming, on the other hand, a producer gas of ordinary quality or one with half of its tarry vapors destroyed in gasification (about which more later on), and that one-half of the remaining tarry vapors are lost in the mains and checker chambers, which is an extravagant assumption, then in the combustion of this gas with air in excess creating a temperature of 3,300 deg. Fahr. each actual cubic foot of the gas mixture in the furnace will, according to the same method of calculation, contain about 4,400 such carbon particles, pretty near as many as those which in a cold state were able to color the waste gases black. The open-hearth furnace chamber would then hold about 15,000,000 incandescent specks of carbon emitting a brilliant white light; and I am sure that it could safely be assumed that they would produce some luminosity. Without a question of doubt, the carbon particles in the gases in the furnace are many times smaller and coagulate to the visible size in which they appear at the top of the stack during the passage through the flues, and consequently it may be assumed that the number of luminous specks in the furnace chamber is too large to be expressed in figures.

Having made this digression to strengthen my statement that the producer gas receives its luminosity from the hydrocarbons, I might take up the argument where I left off and say that it follows that the quality of the gas is improved to the degree in which the tarry vapors in the volatile of the coal are converted into stable hydrocarbons. The question then presents itself: Can the ordinary gas analysis tell us whether the hydrocarbons are more or less preserved in the gas?

I am sure that the majority of combustion engineers will answer, "Yes; the higher B.t.u. in the gas the higher is its quality." This is probably correct in a general way, but I claim that it is not necessarily so and that very often a gas with a fine-looking analysis is defunct in hydrocarbons. In other words, I claim that it is absolutely impossible to tell from the gas analysis whether the hydrocarbons in the tarry vapors have been preserved or destroyed.

To prove this statement I have set forth in Appendix No. 5 a series of detailed calculations based on the analyses of coal and producer gas which I quoted before. You will see from these calculations that the very same analysis can be obtained whether *all* the hydrocarbons have been destroyed and converted into fixed gas, whether they are all preserved but stabilized, or whether part of them are destroyed and part of them preserved. The gas produced from 1 lb. of coal, according to the one or the other condition, might have identically the same analysis, but its physical properties are decidedly different, as the following table will show:

GAS PRODUCED FROM ONE POUND OF COAL

	Cu. Ft. Fixed Gas	Cu. Ft. Tar Vapors	Cu. Ft. Water Vapor	Total Cu. Ft.	B.t.u. per Cu. Ft.	Total B.t.u.
Case 1—all tar vapors destroyed.....	66.3	...	9.1	75.4	103.7	7,822
Case 2—all tar vapors preserved.....	56.9	0.3	9.3	66.5	127.7	8,490
Case 3—50% tar vapors preserved.....	61.9	0.15	9.2	71.0	114.9	8,156

Not only is the total heat value obtained from 1 lb. of coal considerably lessened as the tar vapors are cracked up and fixed, but, what is very much more important, the actual heat value per cubic foot, when the moisture is considered, is in reality not 118 B.t.u., but might be as high as 127.7 B.t.u. or as low as 103.7 B.t.u. And to this you must add the heat transfer capacity, the radiating power of the gas, which, as I hope I have proved, depends entirely on the tarry vapors preserved or, more correctly, on the amount of condensed hydrocarbons contained in the gas.

No doubt the majority of combustion engineers have sometimes been puzzled by the apparently anomalous fact that a gas having a good analysis burnt with a thin flame lacking "body," while another furnace had a sharp, quick-working flame, although the gas analyzed lower. The data presented here ought to give a satisfactory explanation to such puzzles and substantiate my claim that the analysis of the gas does not offer any indication of to what degree the tar vapors remain in the gas. It might be possible, although highly improbable, that the gas production has followed the lines of Case No. 1 with all the vapors reduced to fixed gas. Again, it might be possible, although just as improbable, that all the tarry vapors, according to Case No. 2, remain as hydrocarbons in the gas. Neither is there anything to warrant the assumption that the gasification takes place exactly according to Case No. 3 on a fifty-fifty basis. It might be 75 per cent or more either way. But as long as any assumption has to be made, this condition might just as well be accepted, because, as shown in the following, it offers some simple figures to be used in the calculations, and it is close enough so that the results of the calculations need not be misleading.

The question naturally presents itself: If the quality of the gas chiefly depends on the presence of hydrocarbons and the gas analysis cannot tell anything about it, and consequently is not a dependable indicator of the quality, what is, then, the use of a gas analysis? My answer is that gas analyses are nevertheless very useful as long as they are used with discrimination. They are, to begin with, indispensable in any calculations concerning combustion. They will, furthermore, give a good relative comparison of the operation of the individual producers in a plant where the producers are of the same type and operate on the same kind of coal. Besides, it is possible by means of gas analyses, if taken in a certain way, to determine the real quality of the gas, viz.: whether the majority of the hydrocarbons are destroyed or remain in the volatile.

In a gas producer of the usual design the secondary reactions cracking up the hydrocarbons into fixed gas are generally caused by CO_2 and H_2O attacking the hydrocarbons forming CO and H_2 according to the simplified formulas: $CH_4 + CO_2 = 2CO + 2H_2$, and $CH_4 + H_2O = CO + 3H_2$, in which formulas any paraffine can be inserted in place of CH_4. These reactions occur probably at all times to some extent, but to make them really destructive the CO_2 and H_2O must be present in excessive quantities, which will happen when the fuel bed is thin and full of holes and channels. The steam-air blast will not have time to function properly; the gasification will be very uneven and the gas, in spots, contain principally CO_2, undecomposed H_2O and even oxygen. It is this gas rising through the channels that destroys the hydrocarbons and gives the gas, when sampled in the main, the false appearance of being the result of a good gasification, although the contrary is the case. The correctness of this theory we have proved through a series of gas samples collected inside the producer about a foot above the fuel bed, three short-time samples being taken simultaneously, one close to the side, one at the center, and one half-way in. As the time does not permit any detailed discussion of the very interesting results of the test, I will content myself with saying that the test covered all conditions possible, the fuel bed being deliberately allowed to take care of itself; that is to say, the producer was run at the ordinary rate without any poking, and with intermittent filling, so as to get an uneven fuel bed. It was found that when the producer was in a normal condition the three sets of samples averaged about the same, but that when channels were formed the sample from the periphery or the one from the center, and sometimes both, analyzed very low. Out of 155 sets of samples, or 465 samples in all, 136 had a heat value below 80 B.t.u. and 82 less than 50 B.t.u. Of these 82 samples, 67 had very high CO_2 contents, an average of 15.4 per cent; 5 had an average of 16.7 per cent O_2, and 10 about the same amount of CO_2 and O_2 (average 8.3 per cent CO_2 and 7.5 per cent O_2); in neither could any dissociation of steam have occurred. Comments are really superfluous; a gas of such a composition, even though coming only from a small part of the fuel bed surface, will necessarily have a disastrous influence on the volatile matter distilled off from a considerable area adjacent to the hole in the fuel bed.

Testing individual producers in this manner with three simultaneous samples at various points inside the producer will, without question, tell the condition of the fuel bed and the quality of the gas. We have found this method of testing to have a distinct practical value, particularly for mechanical producers. For example, having once reasons to suspect that the gas from a set of producers, although its analysis apparently was satisfactory, yet lacked in quality, gas samples were taken from all the producers in this manner. The center samples from one of the producers showed a very low B.t.u. value, indicating a thinner fuel bed at the center, due obviously to faulty coal distribution. The distributor was examined and a corner was found to be broken off; after repairs had been made, the quality of the gas was restored to its normal high mark.

But while it thus is impossible to judge the presence of the tarry vapors in the gas from gas analyses, the method imposes additional work on the laboratory and is not suitable for everyday routine work. I would therefore suggest the desirability of adopting another standard from which the quality of the gas could be judged. Formerly illuminating gas was measured by its candle-power. With the advent of gas mantles and gas stoves the value of the illuminating power became of no consequence, while the heating power determined the quality of the gas, and the specifications were changed so that they stipulated a certain B.t.u. value for the gas, omitting any mention of the candle-power. Reversely, I think that the producer gas should be judged by its luminosity and not by its heating value, at least where open hearts are concerned. It certainly would be a great help to the combustion engineers if an instrument were designed that could measure directly the luminosity or the radiating power of the producer gas.

But returning to the discussion of the condensable hydrocarbons, which are distilled over into the gas,

(*Continued on page* 256.)

As the Journal Views It

Building Employee Good-Will

Practically everybody who is connected with the gas industry in any way has some ideas on the subject of building good-will, but it is a notable fact that there are only a few who take up the question of the employee's good-will. When we say few we mean by comparison, for numerous companies are devoting a great deal of time and money to educating their employees as to their ideals. There is no more important question than that of educating the employee not only as to his duties but also as to what the company actually represents so far as it concerns its service to the consumer.

In building good-will among the employees it becomes necessary first to establish a routine of handling every branch of activity of the company. This means not only the work that comes directly in contact with the public, but it means, in addition, work that is done behind the scenes. In other words, if the man who actually comes in contact with the consumers feels that he is being backed up by his entire organization, then his very attitude is bound to create a favorable impression on the consumer. If, however, there is dissension in the organization, it follows naturally that the work of the men is lackadaisical and without any real effort in backing.

Perhaps to some this may seem a minor matter in connection with the actual manufacture and distribution of gas, but there is no more important phase of activity and it remains for the gas industry to recognize this and to devote its constant effort to smooth out its path by building employee good-will.

The Chemical End of the Industry

The Chemical Exposition which held forth in New York the week of Sept. 11-16, inclusive, did a great deal to educate the general public as to the tremendous advances that are being made in the line of development of this vastly important industry. It was particularly pleasing to find a section devoted to gas and other fuel which had many interesting papers and which created a great deal of very favorable comment. The future of the gas industry is closely bound up with the future of the chemical industry, and co-operation will do a great deal for both.

The exposition was of importance also from the fact that in addition to being of service to the gas industry it was likewise of service to the general public, for a great deal of information was broadcast that ordinarily would not be considered as of any interest to the layman.

In another part of this issue will be found abstracts of the various papers that were presented during the week, and these will give a splendid example of the work that was done not only in this connection but in all other branches.

American Gas Journal Daily Convention Issues

at the

American Gas Association Convention

ATLANTIC CITY, OCTOBER 23rd-28th, 1922

Full report of all sessions of every section, including the papers and discussions.

Smashing interviews with prominent men.

Bright, newsy reports of all Convention activities.

Fully illustrated with snapshots, cartoons, etc.

The daily registration of all who attend.

THE AMERICAN GAS JOURNAL DAILY ISSUES

Will be distributed every morning at the convention. All points will be supplied.

Will be mailed each day to every gas company in the United States.

These daily issues will provide a record that all gasmen will preserve and refer to constantly.

The dailies will be the regular size, with distinguishing colors on the cover for each day.

REMEMBER, THE AMERICAN GAS JOURNAL DAILIES WILL BE PUBLISHED "FOR THE GOOD OF THE INDUSTRY"

The Intermittent Gas-Fired Enameling Furnace

(*Continued from page* 249.)

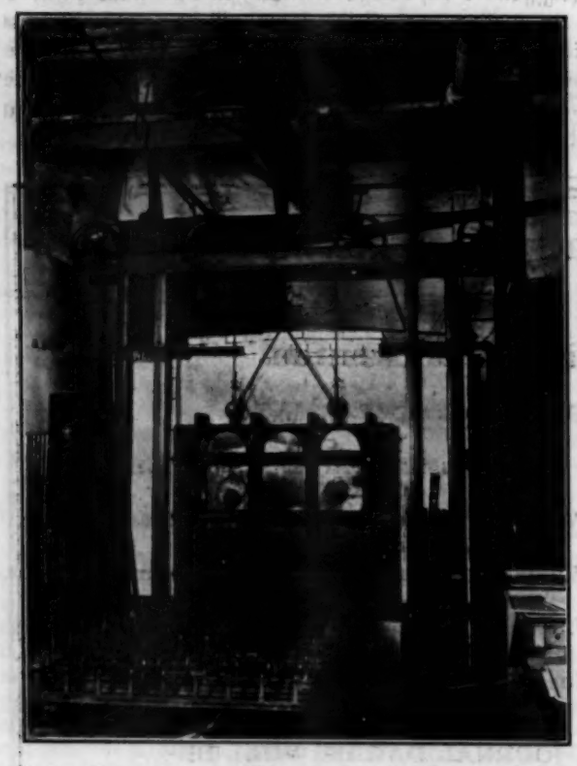
the same size. The cost per hundred square feet should, of course, be taken to arrive at a fair comparison:

Type of Furnace	Square Feet per Hour	Cost per Hour	Cost per 100 Sq. Ft.
Intermittent fired gas	424	$3.24	$0.77
Intermittent fired oil	371	3.00	0.81
Coal fired muffle	140	1.96	1.40
Semi-muffle gas	275	4.02	1.46
Electric	392	6.32	1.61
Full-muffle oil	162	3.30	2.02
Full-muffle gas	162	4.16	2.57

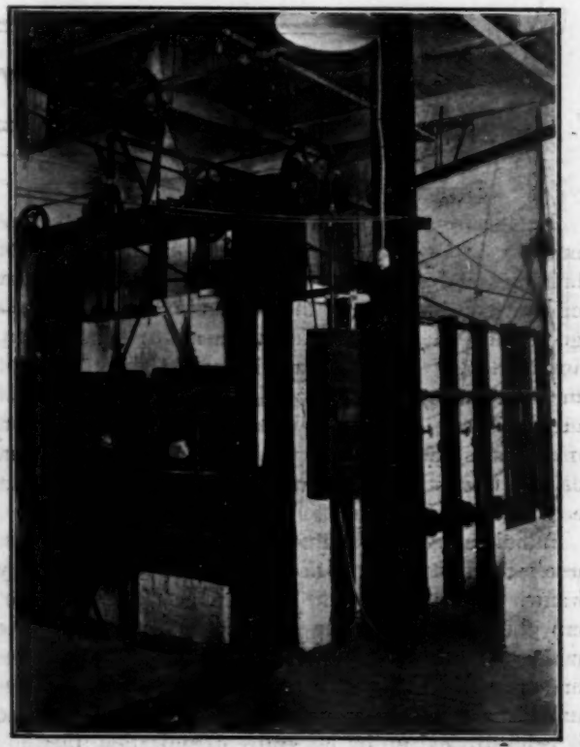
The above costs include the labor of the furnace operators in each case and the fuel is figured on the basis of coal at $5.40 per ton in the bin, oil 6 cents per gallon, electricity 1.5 cents per kilowatt hour and gas at 90 cents per thousand cubic feet.

To the reader it must become evident that the direct-fired gas furnace has the following advantages:

Greater speed.
Absence of spoilage.
Flexible temperature control.
Clean workroom.
No dirt spots on work.
No soot or dust in air or on work.
Compact construction.



Giving Some Idea of How a Solidly Built, Well Insulated Door Is the Most Efficient Proposition in the End



Showing Piping Valves, Gas Burners and Inspirators (Mixers)

No sag in furnace bottom.
Low operating cost.
Practically no repairs.
No muffle.
One hundred per cent of evenly heated interior working space.

Study these points carefully and if you represent the utility company the possibility of a customer using gas for twenty-four hours a day ought to appeal to you. If you are in the enameling industry you will appreciate, without more being said, just what an installation of this order will mean to you.

In any case you agree with me without question, I believe, that "Better business" is "More business."

Combustion of Gaseous Fuels as Judged from Gas Analyses

(*Continued from page* 254.)

they consist, whether all or only a fraction remain in the gas, or tarry vapors and benzene, with a constant percentage of carbon and hydrogen for a given kind of coal.

It is indeed an interesting coincidence—if nothing else—that the hydrocarbons in the coal which I have taken as a basis for my calculations closely correspond in composition to naphthalene, C_1OH_8, because, according to all authorities, napthalene is the predominant hydrocarbon compound that *remains* after the gas has been subjected to heat. It is itself not affected by any pyrogenetic reactions, but is, on the contrary, the result of such reactions on other hydrocarbons. Prof. Berthelot, of Paris, the greatest authority on the subject, has,

among other pyrogenetic reactions, produced the following ones:

$$6CH_4 = C_6H_6 + 9H_2$$
$$2C_6H_6 = C_{10}H_8 + C_2 + 2H_2$$
$$5C_2H_4 = C_{10}H_8 + 6H_2$$
$$C_6H_6 + 2O_2H_4 = C_{10}H_8 + 3H_2$$

In Appendix No. 6 I have set forth more in detail the figures proving this statement and calculations of the true volume of the waste gas from analyses when the presence of the condensable hydrocarbons is taken into account. From them is seen that while the tarry vapors in actual volume only represent one-quarter of 1 per cent, they nevertheless are responsible for 11 per cent of the heat value in the gas and for nearly 7 per cent of the waste gases.

Any calculations as to the products of combustion based on gas and waste gas analyses would accordingly be misleading, unless due consideration is given the tarry vapors. The exact amount, of course, we have no means of determining, but the assumption that, when the producers are operating normally, at least one-half of the tarry vapors are preserved in the gas will give a fairly correct result.

When applying the general formulas, that I presented in Section 2, to producer gas, the following corrections should be made:

$$\text{Formula } 2w = \frac{y + v - o + 3}{x + z - q}$$

3 (cu. ft.) represents the amount of oxygen required by the tarry vapors per 100 cu. ft. dry gas.

$$\text{Formula No. 7: } CO_2 = w\,(h + 2j + k + m + 6n) - (a + 2b + c + e + 6f) - 2.5$$

2.5 (cu. ft.) represents the amount of CO_2 produced from tarry vapors.

The necessity of entering the true volume of the water vapor in the waste gases into the calculations offers another difficult problem, as it cannot be determined directly but involves a knowledge of the ultimate analysis of the coal and the amount of air used in gasification. It will never do arbitrarily to assume a value of the moisture that is contained in the producer gas, and it is possible to arrive at a figure that is sufficiently close so as not to introduce any perceptible error in the calculations. With regard to the moisture resulting from the combustion, 1 cu. ft. should be added to the amount obtained through formula No. 8, this 1 cu. ft. representing the water vapor produced by the combustion of the tarry vapors.

In conclusion I want to call attention to another fact which often is overlooked: the necessity of *two* waste gas analyses when the problem concerns the combustion in an open-hearth furnace, the question being whether the ratio between the gas and the air is correct or whether the combustion is performed in a satisfactory manner. When problems of this nature, involving the combustion in the furnace proper, are to be solved by means of gas analyses, it will absolutely not do to collect the waste gas sample in the flue between the reversing valves and the stack, because there always is a leakage of air into the downtakes and checker chambers, and because there might be a short circuit in the gas reversing valve, introducing combustibles in the waste gas. The sample must be taken as close to the furnace proper as possible—in the ports or downtakes. But due to the construction of the furnace, where the air and gas currents are introduced one above the other on more or less parallel lines and removed in a similar way, a perfect mixture is seldom obtained. A certain amount of gas will sweep closely over the bath; a certain amount of the air sweeps along the roof; between them is a separating blanket of waste gases and the result is that combustibles will show up in a waste gas sample collected from the gas downtake, while a simultaneously collected sample from the air downtake shows free oxygen, indicating surplus air. Under normal operation, when the ratio between gas and air is close, this condition is more the rule than the exception. If only one sample is taken, either from the air or the gas downtake, the result must be erroneous; unless one sample from each of the downtakes is taken, simultaneously with a fuel gas sample (sampling time, of course, in all three cases being inside a reversal or not more than 10-15 minutes) it is useless to attempt any calculations. It is naturally pre-supposed that the ratio in which the waste gases divide between the gas and air ports has been established by observations. This ratio is probably different from every furnace. In the calculations presented in appendix No. 7 I have used a ratio of 45 per cent going through the gas ports and 55 per cent through the air ports, figures that we have obtained from actual measurement. These calculations show that the total amount of waste gases produced was 232.118 cu. ft., that the surplus of air was 10.4 per cent, while the useful air amounted to 96.4 per cent of the air necessary for complete combustion. The ratio of heat development will figure to be 95.85 per cent. If we had contented ourselves with one waste gas analysis, we would have gotten, if we had taken our sample in the air port, 249.374 cu. ft. waste gases (or 7.4 per cent more than actually produced) as a result of complete combustion with a surplus of air as high as 27.2 per cent while, if the sample had been secured from the gas port, the result would have shown 214.018 cu. ft. waste gases (or only 92.2 per cent of the actual amount) with only 91.5 per cent of the possible heat developed because only 92.7 per cent of the necessary air were present.

Importance of Tar Vapors

It may seem inconsistent first to point out the mistake often committed by introducing assumptions in the calculations and then to try to prove my argument against ordinary producer gas analyses by means of an assumed quantity of tarry vapors existing in the gas. But my object was to show the great importance of the tar vapors not to produce a heat balance. In the problems of combustion with which most of the time we have to deal, the question is not about the actual volumes nor of the total heating value, but simply whether the combustion is going on in an efficient way, and whether the proportion of gas and air is satisfactory. The calculations carried out according to my method and based on waste gas analyses collected at the gas port as well as at the air port simultaneously with a fuel gas sample will, under these circumstances, give a sufficiently close

APPENDIX No. 1

Table 1—Table of Chemical Reactions in Combustion

One Cu. Ft.	Requires in Cu. Ft. Oxygen	Air	Produces in Cu. Ft. CO_2	H_2O	N_2	B.t.u. Developed per Cu. Ft. High Value	Low Value
C_2H_4	3.0	14.286	2.0	2.0	11.286	1,591	1,491
CO	0.5	2.381	1.0	...	1.881	324	324
H_2	0.5	2.381	...	1.0	1.881	328	278
CH_4	2.0	9.524	1.0	2.0	7.524	1,012	912
C_6H_6	7.5	35.715	6.0	3.0	28.215	3,810	3,494
C_2H_2	2.5	11.905	2.0	1.0	9.405	.....	1,437
$C_{10}H_8$	12.0	57.144	10.0	4.0	45.144	.....	6,070
H_2S	1.5	7.143	1.0(SO_2)	1.0	5.643	.....	.....

result, even though the presence of tar vapors and water vapors is neglected, particularly as the analyses are presented with only one decimal and it is perfectly satisfactory to compute the figures, on which the judgment is based, with one decimal only.

It has been the purpose of this paper to call your attention to the fact that any guesswork can be eliminated from the solution of ordinary combustion problems by means of waste gas analyses, and to present a method that will extend the possibility of their application as it will establish the relations between a fuel gas and the waste gases even when the combustion is incomplete and part of the CO_2 is derived from the metal bath. I have confined myself to gaseous fuels, but the formulas can easily be modified to apply to liquid fuels as well, provided the assumption is made that they, during a certain stage of the combustion process, are gasified and dissociated into their elements. This assumption is, of course, in reality wrong, but as a purely theoretical chemical proposition it is permissible as the final result of the calculations will be the same.

It has furthermore been my intention with this paper to point out the error so commonly committed in judging the quality and the heating value of producer gas entirely from an analysis of the fixed gases it constains, neglecting the tarry vapors, something that should not be excused with the inability to determine their amount. What is required is, that side by side of the gas analysis another standard be placed, based on the luminosity (candle-power) of the gas. Should I have succeeded in convincing you of the soundness of my arguments and turning your attention towards this new direction, we will undoubtedly in a short time have a practical apparatus that will gauge the contents of tarry vapors in producer gas; and another step would then be taken forward to a more efficient application of fuel for metallurgical purposes.

APPENDIX No. 2

Table 2—Example of Calculation of Total Volume of Waste Gases from Complete Combustion with Surplus Air

Contents	Cu. Ft.	Cu. Ft. O_2 for Combustion	Waste Gases CO_2	H_2O	N_2	B.t.u. per Cu. Ft.
CO_2	12.4	....	12.4	...	....	.....
CO	26.2	13.1	26.2	...	....	84.89
CH_4	0.2	0.4	0.2	0.4	....	2.02
H_2	3.0	1.5	...	3.0	....	9.84
N_2	58.2	...	...	...	58.2	.....
Total	100.0	15.0	38.8	3.4	58.2	96.75
Nitrogen in air		56.43	....	...	56.43	
Grand total		71.43	38.8	3.4	111.63	

We find accordingly that 100 cu. ft. of gas of the given composition requires 71.43 cu. ft. of air and produces a total of 156.83 cu. ft. of waste gases, of which 153.43 cu. ft. are non-condensable and will show in the analysis, which must contain:

CO_2 — 38.80 cu. ft. = 25.288% = 25.3%
N_2 — 114.63 cu. ft. = 74.712% = 74.7%

153.43 cu. ft. = 100.000% = 100.0%

If oxygen is present in the analysis, the following formulas will give the total amount of waste gases and the amount of surplus air, the products of complete combustion being calculated as above:

$$(1)\ A = \frac{Pa}{21-a};\ W = P\frac{21}{21-a};$$

Where A = amount of surplus air.
P = products of complete combustion.
W = total amount of waste gas.
a = percentage of oxygen in waste gas.

Ex: The gas used in the previous example has produced a waste gas of the following analysis:

CO_2 — 23.1%
O_2 — 1.8%
N_2 — 75.1%

$$W = 153.43\frac{21}{21-1.8} = 167.814 \text{ cu. ft.}$$

$$A = \frac{153.43 \times 1.8}{21-1.8} - 14.384 \quad \begin{cases} O_2 = 3.021 \\ N_2 = 11.363 \end{cases}$$

CO_2 = 23.1% = 38.765 cu. ft.
O_2 = 1.8% = 3.021 cu. ft.
N_2 = 75.1% = 126.028 cu. ft. = 114.665 + 11.363

100.0% = 167.814 cu. ft.

The slight discrepancy—CO_2 38.765 against 38.80 and N_2 (from combustion) 114.665 against 114.63—depends on the fact that only one decimal is given in the analysis permitting an error of 0.05%.

APPENDIX NO. 3

Derivation of Formulas for Determining Total Volume of Waste Gases when Combustion Is Incomplete

The method employed is based on the air present, used for combustion or left as a surplus.

1. *Symbols*—

Composition of Fuel Gas	Analysis	Composition of Waste Gas	Analysis	Volume
CO_2	a%	CO_2	h%	hw
C_2H_4	b%	C_2H_4	j%	jw
CO	c%	CO	k%	kw
H_2	d%	H_2	l%	lw
CH_4	e%	CH_4	m%	mw
C_6H_6	f%	C_6H_6	n%	nw
N_2	g%	N_2	p%	pw
O_2	o%	O_2	q%	qw
H_2S	s%			
	100%		100%	100w

The total volume of nitrogen is pw and is composed of the nitrogen in the gas = g plus the nitrogen in the surplus air = 79/21 qw plus the nitrogen in the air used for combustion = 79/21 O, when

$$O = 3\,(b - jw) + \tfrac{1}{2}\,(c - kw) + \tfrac{1}{2}\,(d - lw) + 2\,(e - mw) + 7\tfrac{1}{2}\,(f - nw) + 1\tfrac{1}{2}s - O;$$

$$pw = g + 79/21\ qw + 79/21\ O;\ 21/79\ pw = 21/79\ g + qw + O$$

$$21/79\ pw = 21/79\ g + qw + (3b + \frac{c}{2} + \frac{d}{2} + 2e + 7\tfrac{1}{2}f + 1\tfrac{1}{2}s) - w$$

$$(3j + \frac{k}{2} + \frac{l}{2} + 2m + 7\tfrac{1}{2}n) - o;$$

If we simplify the formula by inserting the following symbols:

$$x = 21/79\ p;\ y = 3b + \frac{c}{2} + \frac{a}{2} + 2e + 7\tfrac{1}{2}f + 1\tfrac{1}{2}s;$$

$$z = 3j + \frac{k}{2} + \frac{l}{2} + 2m + 7\tfrac{1}{2}n$$

and $v = 21/79\ g$; then we get:

$$(2)\quad xw = v + qw + y - zw - o;$$

$$xw + zw - qw = v + y - o;$$

$$w = \frac{v + y - o}{x + z - q}$$

Having thus determined the factor w, we can calculate directly every item of interest:

Total volume of waste gases; $W = 100\ w$

$$(3)\ \text{Air present}\ldots Ap = 100\,\frac{(pw - g)}{79}$$

$$(4)\ \text{Surplus air}\ldots As = \frac{100\ qw}{21}$$

$$(5)\ \text{Air for complete combustion}\ldots\ldots Ac = \frac{100\,(y - o)}{21}$$

$$(6)\ \text{Useful air}\ldots Au = Ap - As = 100\,\frac{(y - zw - o)}{21}$$

$$(7)\ CO_2\ \text{addition}\ldots = W\,(h + 2j + k + m + 6n) - (a + 2b + c + e + 6f)$$

EXAMPLE 1

Analysis of Gas		Analysis of Waste Gas	
CO_2	12.4%	CO_2	24.4%
CO	26.2	CO	1.8
CH_4	0.2	H_2	0.4
M_2	3.0	M_2	73.4
N_2	58.2		100.00%
	100.00%		

$$x = \frac{21}{79} \times 73.4 = 19.51139;\ y = \frac{26.2}{2} + (2 \times 0.2) + \frac{3.0}{2} = 15;\ z = \frac{1.8}{2} + \frac{0.4}{2} = 1.1$$

$$v = \frac{21}{79} \times 58.2 = 15.47089;\ w = \frac{(15.0 + 15.47089) \times 100}{19.51139 + 1.1} = \frac{30.47089}{20.61139} = 1.47835$$

Total amount of waste gases from 100 cu. ft. gas = 147.835 cu. ft.

The air need for complete combustion $= \frac{100\,y}{21} = \frac{1500}{21} = 71.43$ cu. ft.

The air present $= 100\,\frac{(73.4 \times 1.47835 - 58.2)}{79}$

= 63.685 cu. ft. or 86.3 per cent of the air required for complete combustion.

The composition of the waste gases were:

CO_2	24.4%	36.072 cu. ft.
CO	1.8	2.661
H	0.4	0.591
N_2	73.4	108.511
	100.0%	147.835 cu. ft.

Of the combustibles in the gas—
26.2 — 2.661 = 23.539 cu. ft. CO were burnt
3.0 — 0.591 = 2.409 cu. ft. H_2 were burnt

A check-up of these calculations would give:

TABLE 3

Gas Contents	Cu. Ft.	Cu. Ft. O_2 for Combustion	Water Gas CO_2	CO	H_2	N_2	N_2O
CO_2	12.400	.....	12.400	.....	.....	.....	.....
CO	23.539	11.7695	23.539	.....	.....	.....	.....
CO	2.661	.....	.....	2.661	.....	.....	.....
CH_4	0.200	0.4000	0.200	.....	.....	.....	0.400
H_2	2.409	1.2045	.....	.....	.....	.....	2.409
H_2	0.591	.....	.....	.....	0.591	.....	.....
N_2	58.200	.....	.....	.....	.....	58.200	.....
Total	100.000	13.3740	36.139	2.661	0.591	58.200	2.809
Nitrogen in air		50.3120				50.312	
Total air		63.6860	36.139	2.661	0.591	108.512	2.809

The check is not exact, showing a slight variation in the amount of CO_2, which is due to the fact that in the analysis only the first decimal is given—something to which I already have called attention. The correct percentages would in this case be:

CO_2	36.139 cu. ft.	24.434%
CO	2.661 cu. ft.	1.799%
H_2	0.591 cu. ft.	0.400%
N_2	108.512 cu. ft.	73.367%
	147.903 cu. ft.	100.000%

These figures inserted in the equation give—

$$W = \frac{(30.47089 \times 100)}{29/79 \times 73.367 + 0.8995 + 0.2} = 147.903 \text{ cu. ft.}$$

EXAMPLE 2

Were the available air supply sufficient but nevertheless the combustion incomplete, the analysis would, for example, read as follows:

CO_2 ... 23.2%, which in reality should be = 23.218%
CO ... 1.7%, which in reality should be = 1.710%
H_2 ... 0.4%, which in reality should be = 0.380%
O_2 ... 1.0%, which in reality should be = 1.045%
N_2 ... 73.7% (making up the difference) = 73.647%
100.0% 100.000%

$y + v = 30.47089$ (same as in previous example, the gas being the same).

$$x = 21/79 \times 73.647 = 19.57705; \quad z = \frac{1.71}{2} + \frac{0.38}{2}$$

$= 1.045$; $q = 1.045$, which means that the amount of air present happens to be exactly the amount needed for complete combustion.

$$W = \frac{100 \times 30.47089}{19.577705 + 1.045 - 1.045} = 155.645 \text{ cu. ft.}$$

$$\text{Air present} = \frac{100\,[(73.647 \times 1.55645) - 58.2]}{79}$$

$$= 71.429 \text{ cu. ft.}$$

$$\text{Air surplus} = \frac{100 \times 1.045 \times 1.55645}{21} = 7.743 \text{ cu. ft.}$$

$$\text{Useful air} = \frac{100\,[15.0 - (1.55645 \times 1.045)]}{21}$$

$$= 63.686 \text{ cu. ft.}$$

CO_2 surplus $= 1.55645\ (23.218 + 1.710) - (12.4 + 26.2 + 0.2) = 38.799 - 38.8 = O$

EXAMPLE 3

Assuming an incomplete combustion of coke oven gas:

Analysis of Gas		Analysis of Waste Gas	
CO_2	1.8%	CO_2	9.6%
C_6H_6	0.1	C_2H_4	0.1
C_2H_4	2.1	O_2	0.8
O_2	0.8	CO	0.2
CO	7.0	H_2	2.6
H_2	58.4	CH_4	0.7
CH_4	24.8	N_2	86.0
N_2	4.8		100.0%
H_2S	0.2		
	100.0%		

$$w = \frac{y + v - O}{x + z - q}$$

$$y = (3 \times 2.1) + \frac{7.0}{2} + \frac{58.4}{2} + (2 \times 24.8) + (7\tfrac{1}{2} \times 0.1) + (1\tfrac{1}{2} + 0.2) = 89.65$$

$$v = \frac{21}{79} \times 4.8 = 1,27595; \quad O = 0.8;$$

$$X - \frac{21}{79} \times 86.0 = 22.86076$$

$$z = 3 \times 0.1 + \frac{0.2}{2} + \frac{2.6}{2} + 2 \times 0.7 = 3.1; \quad q = 0.8$$

$$w = \frac{89.65 + 1.27595 - 0.8}{22.86076 + 3.1 - 0.8} = \frac{90.12595}{25.16076} = 3.5820$$

The waste gas produced from 100 cu. ft. gas (not counting the H_2O produced nor the moisture contained in the gas) amounts to—

CO_2	9.6%	34.387 cu. ft.
C_2H_4	0.1	0.358
O_2	0.8	2.866
CO	0.2	0.716
H_2	2.6	9.313
CH_4	0.7	2.507
H_2	86.0	308.053
	100.0%	358.200 cu. ft.

$$\text{Air present} = \frac{(308.053 - 4.8)}{79} = 383.865 \text{ cu. ft.}$$

$$\text{Air surplus} = \frac{100 \times 2.866}{21} = 13.648 \text{ cu. ft.}$$

Useful air = 270.217 cu. ft.

$$\text{Useful air} = 100 \frac{(89.65 - (3.1 \times 3.582) - 0.8)}{21}$$

= 370.218 cu. ft.

$$\text{Air for complete combustion} = 100 \times \frac{(89.65 - 0.8)}{21}$$

= 423.995 cu. ft. Only 90 per cent of the necessary air was accordingly present, and 87.5 per cent active.

$$\text{Surplus } CO_2 = 3.582\ (9.6 + 2 \times 0.1 + 0.2 + 0.7) - (1.8 + 2 \times 2.1 + 7.0 + 24.8 + 6 \times 0.1)$$

= 38.3274 — 38.4 (a slight discrepancy due to simplification of percentages of fuel gas and waste gas to one decimal).

In this connection it may be well to point out the necessity not to overlook the moisture carried by the fuel gas and produced in the combustion. The coke oven gas will carry at least three cubic feet of vapor per 1,000 cu. ft. of gas, and if the combustion were complete the products of the same per 100 cu. ft. of gas would amount to 377.4 cu. ft. non-condensable gases, 112.9 cu. ft. of vapor from the combustion and 3 cu. ft. of vapor from the gas itself, or a total of 493.3 cu. ft., of which the gas shown in analysis and calculated would be only 76.5 per cent.

The amount of water vapor resulting from the combustion is found through the following formula:

$$(8)\quad H_2O = (2b + d + 2e + 3f + 2s) - w\ (2j + 1 + 2m + 3n + 2s)$$

if s = % H_2S in fuel gas; S = % H_2S in waste gas and the SO_2 formed is counted with the H_2O.

Developments in Gas Technology

Important Information Gathered from All Parts of the World

By ISMAR GINSBERG, B.Sc., Chem. Eng., Associate Editor

Recovery of Iron from Purifying Mass

Highly heated iron or iron oxide is used in the recovery of the iron used to purify producer gas. The mixture of iron or iron oxide, which contains the ferrous sulphide formed by the iron in the purifying mass combining with the sulphur in the gas, is melted in the producer itself and the ferrous sulphide reacts with the lime in the hot clinker slag in contact with the incandescent carbon of the producer charge with the production of pig iron. The process can be made continuous, the purifier being built as an extension of the producer. This apparatus and process are patented by Koppers, German Patent No. 343,943.

The Structure of Coke

This is the name of an article published in the *Journal of the Society of Chemical Industry*, 1922, page 181T, which is a study of the process of the formation of high-temperature coke. There are three stages in this process. The first stage reaches up to a temperature of 550 deg. Cent., in which the initial cell formation is effected. These cells have relatively thick walls of soft material of low specific gravity. The process is accomplished by a swelling of the charge. The second stage is between the temperatures of 550 and 850 deg. Cent. During that period the mass as a whole shrinks and an increase in specific gravity of the coke material ensues, the resulting coke having thinner but stronger walls and the porosity reaching a maximum. In the last stage the predominant feature is the further contraction of the entire mass, but the coke material does not undergo any appreciable increase in specific gravity. The result is a strong coke with relatively thick walls and constituted of small pores. The temperature reaches a maximum of 1,100 deg. Cent. The specific gravity of the coke never reaches that of graphite, 2.3.

Steam Decomposition in Producer Gas Process

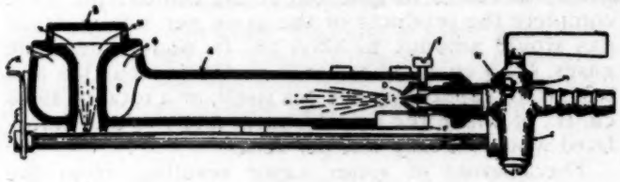
In *Das Gas und Wasserfach*, 1922, pages 257-261 and 277-280, there is described an instrument for measuring the amount of steam in gas. The instrument depends on the local reduction in pressure in a pipe caused by a constriction. Where two constrictions are employed, and the water vapor removed between them, the additional loss of pressure is a measure of the volume of the water vapor. The theoretical and mathematical principles, on which this instrument is based, are discussed in detail.

Core Oils from Tar Oils

The oils that are derived from coal tar in the regular process of distillation can be used to good advantage in the manufacture of core oils for use in iron foundries. The tar oils, that are selected for this purpose, have a boiling point of 220 to 400 deg. Cent. These oils may also be made from lignite tar or wood tar. They are mixed with fat pitch, for example, stearine pitch, or resin oil, resin, or resinlike substances, such as coumarone resin. For further details see British Patent No. 179,203.

New Swiss Gas Burner

The burner is described in detail in Monats Bulletin No. 6, pages 105 to 108. The accompanying figure shows the construction of the burner. The regulating cap is seen at D. This is conical in form and is provided with four openings. The set screw E fixed it in any desirable position. While this device regulates the flow of gas, the flow of air is regulated at F. At the end of the burner there is located the screw I, which holds the plate K in position. The air is fed to the gas through the tube L. The position of this tube can be raised or lowered with respect to the burner head B by means of the plate K. In this manner the quantity of air is increased or decreased.



Warm Winter Predicted

Harry Prince, a grandson of the great Indian chief, Peguis, now in Manitoba, where it gets pretty darn cold in the winter season, is quoted as saying that we will have an open fall and no cold weather until late in December.

"The 'dipper' is exceptionally slow in its turning movements this season and this is an unfailing sign of a long continuance of warm weather, said Mr. Prince.

It's a brave man that will attempt to prophesy the weather, but then Mr. Prince comes from a long line of "big braves" and let us hope that his prediction is all too true because it will allow the poor gasman to buy enough coal to "tank up," and this will establish an "inflated business" that all gas users like to see.

Distilling Coal Tar

The apparatus which is patented in British Patent No. 158,875 is for the continuous distillation of coal tar. The advantages of this apparatus are as follows: Economy and simplicity of construction by reason of low temperatures and pressures employed; absolute continuity of operation; possibility of treating products of a defective quality; obtaining of a non-inflammable tar; constancy and purity of the products produced.

Manufacture of Gas

Low-grade gas is passed through incandescent fuel such as coke, and the highly heated gas is then enriched by its passage through a retort containing coal or shale. The coal through which it passes is partially carbonized and the coke that is produced thereby is suitable for domestic purposes. During the process tar is produced in large quantities. This process enables the use of very inferior coals for the purpose of enriching low-grade gas and recovering tar and other by-products. The vessel, which contains the incandescent coal, may have ordinary atmospheric or oxygenated air admitted to or blow through the coke at suitable intervals, so as to bring it to the necessary high temperature. This is done in much the same way as the blow in a water gas system. The waste gases from such blows may be used for externally heating the coal retorts.

The apparatus for carrying out the process is shown in the accompanying figure. Figure 1 is the producer. Air enters at a; the bed of fuel is b. The rich gases pass out at e. The low-grade gas leaves

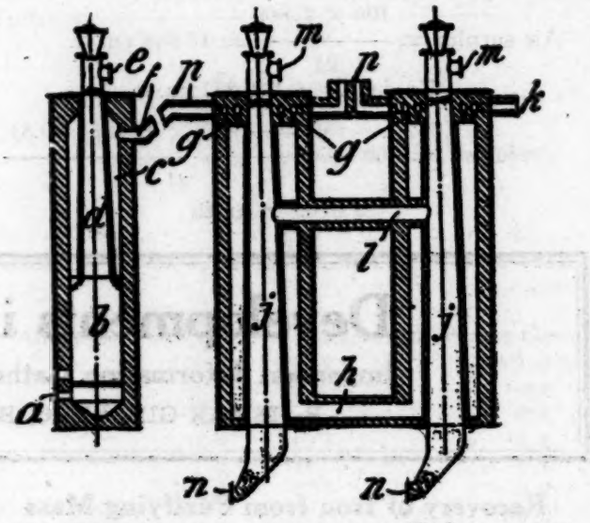


Fig. 1. Fig. 2. Fig. 3

at f and enters the top of the retort setting (Fig. 2). It is there burned with air, the products of combustion passing down the sides and through h into the second retort (Fig. 3), and out through k to the stack. The coal contained in the retorts is gradually carbonized. The rich gases from the second retort pass through l into the first retort. The process is reversed when the first retort is being recharged with new coal. (See British Patents Nos. 181,403 and 181,404.)

Cheap Gas to Manufacturers

Amarillo, Texas, is prepared to offer natural gas to factories at less than 7 cents a thousand cubic feet, it was developed at a recent meeting of the board of city development. Just how much less than 7 cents was not indicated. Geological surveys show that Amarillo has one of the largest natural gas fields in the world. The daily production is now around 600,000,000 cu. ft., and not over 4,000,000 of this is being used. The wells directly supplying the city of Amarillo have a capacity of 123,000,000 cu. ft.

Chemical Exposition Discusses Gas

Abstracts of Papers Presented at Gathering in New York

A NEW ELECTRIC FURNACE FOR THE DETERMINATION OF THE BY-PRODUCT YIELDS

By Harold J. Rose

The by-product yields obtainable from coal when coked in a by-product coke oven may be determined by laboratory distillation tests.

Since the yield of by-products is seriously affected by small variations in distillation conditions, the laboratory determination requires the most rigidly controlled testing conditions.

For this purpose a furnace, consisting of a deep trough formed from a number of U-shaped electrical heating units with individual control has been developed, and is in regular use for research and testing purposes.

Typical results are given to show the agreement of duplicate determinations made with this apparatus. The furnace is described and fully illustrated.

BITUMINOUS COAL AS WATER GAS GENERATOR

By William A. Dunkley

Conditions leading to experiments with bituminous coal as water gas fuel; when its use is warranted; chemical and thermal reactions of the water gas fuel bed; maintenance of the thermal balance in the fuel; importance of fuel-bed condition in maintaining thermal balance; depth, permeability and uniformity of fuel bed essential to good operation; the bituminous fuel bed less permeable than the coke fuel bed, also likely to be less uniform; bituminous coal inactive in water gas production until coked; heat loss due to evolution of volatile matter of coal during blow period; methods employed to improve fuel-bed conditions with bituminous coal; the "blow-run" as a means of preserving the thermal balance and saving fuel; capacities now realized with coal; fuel efficiencies obtained with coal; experiments with coal and coke mixtures; value of experience gained from operation with coal and fuel mixtures.

THE FORMS OF SULPHUR IN COKE—A PHYSICO-CHEMICAL STUDY OF THE SULPHUR HELD BY CARBON AT HIGH TEMPERATURES

By Alfred R. Powell

A phase-rule study of the system, carbon-sulphur, at high temperatures showed that the sulphur exists in two distincetive forms—(1) a very stable form which exhibits all the properties of a solid solution, and (2) free sulphur physically absorbed by the carbon. Coke may contain both of these forms in addition to some sulphur combined with iron as ferrous sulphide. At temperatures in the neighborhood of 500 deg. Cent. the ferrous sulphide of coke oxidizes very readily in the presence of air to ferric oxide and free sulphur. This reaction seems to occur during the quenching of coke and explains the disappearance of ferrous sulphide from coke rather than any reaction which occurs during the coking process.

THE FRACTIONAL DECOMPOSITION OF COAL AND COAL COMPONENTS

By S. W. Parr and T. E. Layng

Next to the fractionation of coal by solvents the fractional decomposition of coal in its combined form and also of its separate type constituents has furnished the most valuable data concerning the character of different types of coal and their behavior in the process of decomposition. Investigators in this field heretofore have failed to appreciate the significance of oxygen either combined or absorbed, but especially the role of the oxygen held in some form of absorption. The results as interpreted from the standpoint of this investigation have an entirely new meaning and are of fundamental importance in connection with studies along the line of coal carbonization.

THERMAL OPERATION OF MODERN REGENERATOR COKE OVENS

By D. W. Wilson, H. O. Forrest and C. H. Herty, Jr.

Briefly stated, there have been included in this report: First, discussion of data needed to show completely the thermal operation of a modern regenerator coke oven battery; second, description of the experimental methods employed to obtain the needed data, together with a table giving experimental figures obtained; third, a table balancing total heat input against total heat output is given, with a discussion of this and a calculation of the efficiency of the ovens; fourth, a so-called sensible heat balance is tabulated, the net heat effect of the coking process is discussed and the relation between the sensible heat balance and the exothermicity of the conversion from coal to coke is indicated.

THE SOFTENING POINT OF COAL—ITS DETERMINATION AND SIGNIFICANCE

By T. E. Layng, W. S. Hawthorne and A. W. Coffman, with S. W. Parr

Reported by T. E. Layng

References to the softening point of coal are frequent in fuel literature. The term heretofore has had a very vague meaning. This paper describes a method for its determination at once simple and accurate. The interesting fact has been developed that under uniform conditions the softening point repeats itself with marked constancy. Moreover, it is evidently a characteristic factor for varying types of coal as also for coal which has been for different lengths of time in storage. That is to say, it is a value which runs parallel with the oxygen content. No less striking is the solidifying temperatures, which result in a curve symmetrical with the range exhibited for the soften-

ing temperatures. Description of the apparatus with results on numerous coals are given. The results are exceedingly interesting and may answer such questions as, What is the type of coal? What would be its behavior in storage? What kind of coke would it make and what modification of existing methods would improve its coking qualities? The report is preliminary only and further experiments are in progress.

A PROPOSED THEORY OF COAL CARBONIZATION

By S. W. Parr and T. E. Layng

Reported by S. W. Parr

This paper presents the summarized results of the several contributory lines of investigation on topics directly related to the carbonization of coal. The evidence seems to be conclusive that a correct theory for coal carbonization has yet to be written. It is not to be inferred that its final formulation is attempted in this paper. However, the results now in hand point out the general outline.

The basic principle seems to be that the bonding effect which results in the production of a coherent mass, is due not only to the presence of bituminic material, but to the absence or control of deleterious products of decomposition from the cellulosic substance, which under certain conditions may weaken or completely nullify the bonding property of the bituminic bodies. The production of coke is therefore not a simple matter of destructive decomposition of organic matter, but a destructive decomposition accompanied by cross reactions which may, under varying circumstances, produce an altogether different result as to the physical character of the final product. The paper is a preliminary report only.

METHODS OF UTILIZING THE COKE PRODUCED BY LOW-TEMPERATURE CARBONIZATION OF COAL

By Harry A. Curtis

The coke obtained by low-temperature carbonization of coal is soft, light and quite unsuited for general use as a smokeless fuel. Attempts have been made to increase the density of the coke by compressing the coking coal mass in the retort, but these methods have not attained commercial success. By pulverizing the soft coke it can be burned efficiently in powdered fuel equipment, but preliminary tests of the fuel on a Coxe stoker gave unsatisfactory results. By grinding the coke, briquetting it and carbonizing the briquets a very high-grade smokeless fuel is obtained, but the cost of these operations is high.

A SPECIFIC APPARATUS FOR GASES

By T. R. Weymouth, R. P. Anderson and J. R. Fay

This new device consists of a thin orifice and a small capillary tube in series and makes use of the fact that the differential pressure resulting from the steam-line flow of gas through a capillary tube is independent of the specific gravity of the gas while the differential pressure resulting from the flow of gas through a thin orifice varies directly with the specific gravity of the gas. The flow of gas through the orifice is kept constant by holding a certain differential pressure on the capillary tube and the differential pressure on the orifice is calibrated to read specific gravity of the gas.

THE BECKER COMBINATION COKE OVEN

By Harold J. Rose

The latest advance in by-product coke oven design is represented by the Becker combination oven, a modification of the Koppers oven.

Greater heating efficiency, better coke quality, and increased strength of construction are obtained by a novel design which provides for the heating and regeneration of the coke and pusher ends of each oven as separate units. In this construction, gases of combustion pass over the top of each oven and down through the opposite flues of the same end, instead of passing longitudinally to the end of the same line of flues.

Details of design will be fully illustrated by means of lantern slides.

METHODS FOR STUDYING THE MACROSTRUCTURE OF COKE

By Harold J. Rose

The study of the structure of coke has been greatly neglected, due largely to the difficulties involved in preparing specimens, and in satisfactorily reproducing the structure photographically.

This paper opens the way to the comprehensive study of coke macrostructure, by the use of novel methods.

After sectioning the coke, the author impregnates the cut surface with a white, hydraulically hardening compound, after which it may be polished to any desired degree. The excellent contrast of black coke with white impregnating compound makes detailed study and reproduction an easy method.

Another novel method is the direct reproduction of the coke surface as obtained by inking the polished coke surface and printing with it on enameled paper.

The article is copiously illustrated with macrophotographs.

THE COMBUSTION OF COAL WHICH HAS BEEN A LONG TIME IN STORAGE

By S. W. Parr and T. E. Layng

Reported by S. W. Parr

It has been fairly well demonstrated that coal in storage does not lose any appreciable number of heat units. Previous investigations show the seeming loss in B.t.u. to be due to a corresponding increase of weight resulting from absorbed oxygen. However, when coal, especially fine material, which has been long in storage is burned, the result is very likely to show a low efficiency and indeed such coal sometimes seems to be unwilling to burn at all.

The results noted in this paper account for the behavior of such coal to be due to the fact that coal in the finer sizes, especially coal of the mid-continental type, has a very large absorptive capacity for oxygen; that because of the colloidal character of the coal substance such absorbed or adsorbed oxygen is held so tenaciously that when discharged by heat it has reached the combining stage and goes off as CO_2. The blanketing effect of this gas over the fuel bed results in a deadening of the fire and a loss of efficiency.

Public Utilities Securities Market Report

Prices of Representative Gas Bonds

(Quotations furnished by The National Surety Company)

Company		Maturity	Sept. 14, 1922 Bid	Asked
American Lt. & Trac. Co.	Five Year 6s	May 1, 1925	107	108
Brooklyn Union Gas Co.	First Consol. 5s	May 1, 1945	98¼	99½
Columbia Gas & Elec. Co.	First 5s	May 1, 1927	95½	96⅛
Consol. Gas, Elec. Lt. & Pr. Co. of Baltimore	First Ref. 7½s	Dec. 1, 1945	110	111
Consol. Gas, Elec. Lt. & Pr. Co.	General 4½s	Feb. 14, 1935	92	93½
Consol. Gas Co. of New York	Sec. Conv. 7s	Feb. 1, 1925	102	—
New Amsterdam Gas Co.	First Consol. 5s	Jan. 1, 1948	88	90
Denver Gas & Elec. Co.	Gen. (now 1st) 5s	May 1, 1949	90½	91
Detroit City Gas Co.	Gold 5s	Jan. 1, 1923	100	—
Equitable Illum. Gas Lt. Co. of Philadelphia	First 5s	Jan. 1, 1928	98	100
Hudson County Gas Co.	First 5s	Nov. 1, 1949	91	93
Laclede Gas Light Co.	Ref. & Ext. 5s	Apr. 1, 1934	90	96
Louisville Gas & Elec. Co.	First & Ref. 7s	June 1, 1923	100¼	101¼
Michigan Light Co.	First & Ref. 5s	Mar. 1, 1946	90	92
Milwaukee Gas Light Co.	First 4s	May 1, 1927	94⅛	95
Pacific Gas & Elec. Co.	Gen. & Ref. 5s	Jan. 1, 1942	93¾	94¼
Pacific Gas & Elec. Co.	First & Ref. 7s	Dec. 1, 1940	108	109½
Cal. Gas & Elec. Corp.	Unif. & Ref. 5s	Nov. 1, 1937	97½	98
Peoples' Gas Lt. & Coke Co.	Refunding 5s	Sept. 1, 1947	96	96½
Chicago Gas Lt. & Coke Co.	First 5s	July 1, 1937	97	98
Portland Gas & Coke Co.	First & Ref. 5s	Jan. 1, 1940	91½	93½
Seattle Lighting Co.	Refunding 5s	Oct. 1, 1949	83½	85
Southern California Gas Co.	First 6s	Nov. 1, 1950	98	—
Utica Gas & Electric Co.	Ref. & Ext. 5s	July 1, 1957	91¾	—
Washington Gas Light Co.	General 5s	Nov. 1, 1960	94	95
Western States Gas & Elec. Co. of California	First & Ref. 5s	June 1, 1941	91	92

Publicity Utility Taxes Raised 102 Per Cent in Missouri 1915-1921

Jefferson City, Mo.—Customers of privately owned electric, gas, telephones, water supply and electric railway companies in Missouri had the neat little sum of $6,328,-404.14 added to their bills for utility service during 1921 by Federal, State and local taxation authorities.

This is $3,206,234.92 more than the $3,122,233.92 that these utility customers paid in taxation in 1915.

The increase in public utility taxation in Missouri in 1921 over 1915 was 102.57 per cent, while the increase in number of companies was but 7 per cent, according to figures compiled from State records by the Missouri Committee on Public Utility Information.

While taxation, labor, supplies, costs of operation, generally have increased over 100 per cent, 1915 to 1921, increases in rates charged customers have averaged but 40 per cent, according to the same authority.

Comparative figures show that the steam railroads of Missouri paid in 1921 a total of $5,694,323.26 in taxation, $634,280.88 less than the $6,328,404.13 paid by the electric, gas, water supply, electric railway and telephone companies.

The total tax paid by the utilities in 1921 was almost three times as much as the total paid in State corporation taxes ($2,962,876.37), and almost $2,000,000 more than received by the State from its largest single source of revenue, the State income tax, which was $4,794,-495.75 in 1921 and almost twice as much as the automobile license tax ($3,500,000).

The figures show that water supply, the most indispensable of all public utility services, sustained an increase in taxation of 248.669 per cent in 1921 over 1915, electric companies 170.18 per cent, electric railways 70.80 per cent, heating companies 605.48 per cent, telephone companies 85.24 per cent and gas companies 69.21 per cent.

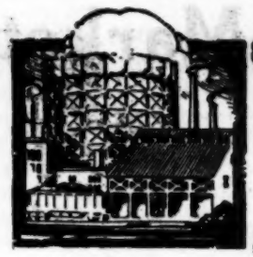
Growth of Dallas Is Seen in Mains Extensions

Dallas, Tex.—Twenty-three miles of gas line have been ordered by the Dallas Gas Company since the beginning of the current year. Of this amount sixteen miles have been laid. Delay in movement of pipe from the factories due to the railroad strike has prevented the laying of more. The company has seven carloads of pipe tied up in one terminal in the East at this time, and its work is delayed by this shortage of materials.

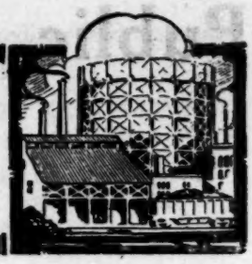
Total orders for pipe for extensions by the company so far this year include 53,964 ft. of 4-in. and smaller, 29,930 ft. of 6-in., 21,623 ft. of 8-in., 9,758 ft. of 10-in. and 5,619 ft. of 12-in.

The length of new gas lines laid in Dallas this year will be between twenty-five and thirty miles, unless the strike shall continue to delay movement of materials for this construction. It indicates a rapid growth of the city and a substantial increase in the use of gas by the residents.

The plant of the Dallas Gas Company has been kept in the best possible condition and efforts of the company to serve its customers extend in addition to supply the gas to advise and co-operation in economical use of gas and in the prevention of accidents and fires from use of gas.



NEWS OF THE GAS INDUSTRY



Tough Made Chief Petroleum Technologist

F. B. Tough, United States supervisor of oil and gas operations on leased public lands, has been appointed chief petroleum technologist of the Bureau of Mines, to succeed A. W. Ambrose, made assistant director of the bureau. Mr. Tough's appointment is effective Oct. 1.

Mr. Tough holds the degree of engineer of mines from the School of Mines, Columbia University, New York. Before entering the service of the Bureau of Mines he had several years' experience as resident geologist for the Southern Pacific Company in various oil fields in California. After coming with the Bureau of Mines, Mr. Tough specialized in problems dealing with the exclusion from oil and gas wells of encroaching underground waters. Bulletin 163, "Method of Shutting Off Water in Oil and Gas Wells," written by Mr. Tough, has been widely circulated. In 1919 and 1920 Mr. Tough was in charge of conservation work in the Wyoming oil fields, under the co-operative agreement with the Rocky Mountain Petroleum Association. Under this agreement the Rocky Mountain Petroleum Association contributed $30,000 a year to enable the Bureau of Mines to demonstrate methods of drilling and operating wells in order to minimize the waste of oil and gas and damage to oil and gas sands. The results obtained in the two years' duration of this work have been published in a special report issued by the association.

In the spring of 1920 Mr. Tough was appointed United States supervisor of oil and gas operations under the provisions of the general leasing act, continuing, however, to act as engineer in charge of the Rocky Mountain Petroleum Association work until its completion, the two pieces of work overlapping by about six months.

As supervisor of oil and gas operations it became his duty to develop a system and organize a corps to supervise gauging of oil and the metering of gas produced from Government lands, and to supervise drilling and producing operations thereon with a view to the prevention of surface and sub-surface waste. While much remains to be done, it may be noted that well-equipped offices in charge of experienced oil men have been established in the various centers of production from Government lands. Through these men and their associates the Government's interests in these oil properties are being protected. Although the leasing act and regulations established under it provide wide discretionary powers for the supervisor and his representatives, it has been the constant effort to avoid anything in the nature of a paternal despotism. The problems that have arisen in connection with this work have been attacked as common alike to the Government and the operators on Government land. Results have shown that a practical problem in the oil industry which cannot be solved by such means is a very knotty one indeed.

Frank H. Knapp Is Elected President of Pittsburgh Water Heater Co.

Frank H. Knapp has been elected president of the Pittsburgh (Pa.) Water Heater Company, to succeed the late John Jay Edson. Mr. Knapp was appointed general manager of the company six years ago. For twenty-five years previous to that he was in the plumbing supply business. In 1921 he was elected a director of the American Gas Association, and is well known throughout the gas fraternity.

Installs Gas in Town Farm

Bridgeport, Conn.—Plans are being made for the installation of gas equipment in Hillside Home, Bridgeport's town farm. For the first time in the history of the institution the coal supply has been exhausted. The city is unable to purchase any more coal, and it has been decided to equip the home with gas.

Editor Joins Sales Force

C. E. Reese, editor of the Gas Engineering Appliance Catalogue and associate editor of the *Gas Age-Record,* has joined the stoker sales department of the Westinghouse Electric & Manufacturing Company, at South Philadelphia. He was previously cadet engineer and combustion engineer with Henry L. Doherty & Co., and assistant engineer of the Illinois Public Utilities Commission. Mr. Reese is a graduate gas and electrical engineer and a member of the editorial conference and executive committee of the New York Business Publishers Association, Inc., American Gas Association, American Institute of Electrical Engineers, graduate salesman of the National Commercial Gas Association and graduate in the industrial publishing course given by the New York Business Publishers Association, Inc. Mr. Reese will work with G. A. Sacchi, manager of the stoker sales department, and R. R. Davis, manager of the department of publicity at East Pittsburgh.

62,000,000-Ft. Well

One of the largest gushers from a shallow depth ever completed in the mid-continent fields was recently brought in on the wildcat lease of the Iowa Oil & Refining Company, located in Grady County, Okla. The well has shown a maximum flow of 62,000,000 ft., with a rock pressure of 585 lb. The gas flow started at a depth of 1,107 ft. after 64 ft. of sand had been penetrated.

The Oklahoma Natural Gas Company has entered into a tentative agreement to purchase the output of the gasser. The company is a large distributor of natural gas for commercial and domestic uses. The company has a main line running within half a mile of the well.